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REPORT ON ATMOSPHERIC ENVIRONMENT INTERACTIONS WITH FREE AND TETHERED BALLOONS

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AIR-LAUNCHED BALLOON SYSTEM
VOR
TETHERED
ADIABATIC
BALLOON-FLIGHT SIMULATOR

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

THIS REPORT CONTAINS INFORMATION IN FOUR AREAS: (1)

I AIR-LAUNCHED BALLOON SYSTEM (ALBS): PROGRAMS, THEIR DESCRIPTION, FLOWCHARTS, AND DOCUMENTATIONS.

II BALLOON TRACKING USING VOR: DESCRIPTION AND LOGIC OF MATHEMATICAL DEVELOPEMENT, AND A PROGRAM EMPLOYING (over) → next

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cont

THESE TECHNIQUES (INCLUDING FLOWCHART AND DOCUMENTATION).

III TETHERED BALLOON EXPERIMENT: ANALYSIS AND RECOMMENDATIONS

IV BALLOON FLIGHT SIMULATIONS USING EGLIN AFB, HOLLOMAN, AND WHITE SANDS WIND DATA.

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INTRODUCTION

This report contains information in four areas:

(1) ~~I.~~ Air-Launched Balloon System (ALBS): Programs, their description, Flowcharts, and Documentations;

(2) ~~II.~~ Balloon Tracking Using VOR: Description and Logic of Mathematical Development, and a Program Employing These Techniques (Including Flowchart and Documentation);

(3) ~~III.~~ Tethered Balloon Experiment: Analysis and Recommendations; and

(4) ~~IV.~~ Balloon Flight Simulations Using EGLIN AFB, HOLLOMAN, and WHITE SANDS Wind Data.

I. ALBS Program Documentation

Introduction

This write-up describes programs pertaining to the Air-Launched Balloon System (ALBS), which were originally written for a desk-top calculator (Wang Model 452-1), by Andrew Carten (AFGL), ALBS development program manager.[1] These programs have now been put in Fortran so that they may be run on the the CDC 6600, and this section provides all information necessary to run these programs. For each program are provided a description, listing, flow chart, sample deck set-up, sample output, and definitions of all nomenclature, i.e., the variable names, used in the program. As much as possible, the original program names, subroutine names, and variable names have been retained. The underlying mathematics and logic, unless different, are not described in any depth here. For a more comprehensive treatment the reader should consult the Carten report.[1]

The first program, called CHUTE, treats the ALBS system as the drogue and main parachutes are being deployed. The second program, called P14B, treats the system as the balloon is being inflated.

Note that within the descriptions, flow charts, etc. variable names are often referred to without explanation. The reader is referred to the appropriate section on 'Nomenclature'.

Program CHUTE

This program computes theoretical-performance data (velocity, drag, dynamic pressure, etc.) for the ALBS system starting from the point when either the drogue parachute or the main parachute is beginning to open until it is fully opened ($0 \leq t \leq TF$). The computations are based on an initially chosen opening time (TF=TFI). The volume of the filled parachute is then computed. If the calculated volume, using the initial opening time, is sufficiently close (less than 200 cu ft) to the theoretical volume, the program goes on. If not, a new opening time is chosen, and the first calculation is repeated.

When an acceptable opening time has been found, the behavior of the system at $t \geq TF$ is computed. The calculations are continued until the velocity of the system is 'sufficiently close' to the equilibrium velocity (VEHI). The criterion for 'sufficiently close' is satisfied when the change in the dynamic pressure (Q) becomes 'very small'. The system data at this point become the starting data for another program not described here.

The program then reverts back to the time period during which the parachute was in the process of opening ($0 \leq t \leq TF$), and it calculates deceleration and opening shock forces.

Data input to the program is by means of a READ statement. Each time the READ statement is executed, i.e., each line (or card) of input data is read a new set of calculations is done. Any number of sets of calculations may be done at one time. In this way, parametric studies of any of the parameters in the READ statement can be done easily. The data must be 'unformatted', i.e., the variables must be separated by commas.

Each time a new opening time (TF) is tried, subroutine P4U is called with its first argument equal to 0, and one page of output is written. When an appropriate opening time is found, P4U is called again, but this time with its first argument equal to 1, and calculations are made for t>TF. This output is printed on the same page. Subroutine P10 is then called to calculate the acceleration and opening shock forces, and this output is written on a new page.

The output of the program is written on tape 1 and tape 2. Tape 1 contains the output of main interest, while on tape 2 is written supplementary information as well as results of calculations used for checking purposes.
(Note that in the program there are statements with 'CHECK' written in the first 5 columns. Because there is a 'C' in column 1, they are treated by the computer as comment cards. In order to use those statements the 'CHECK' must be deleted.)

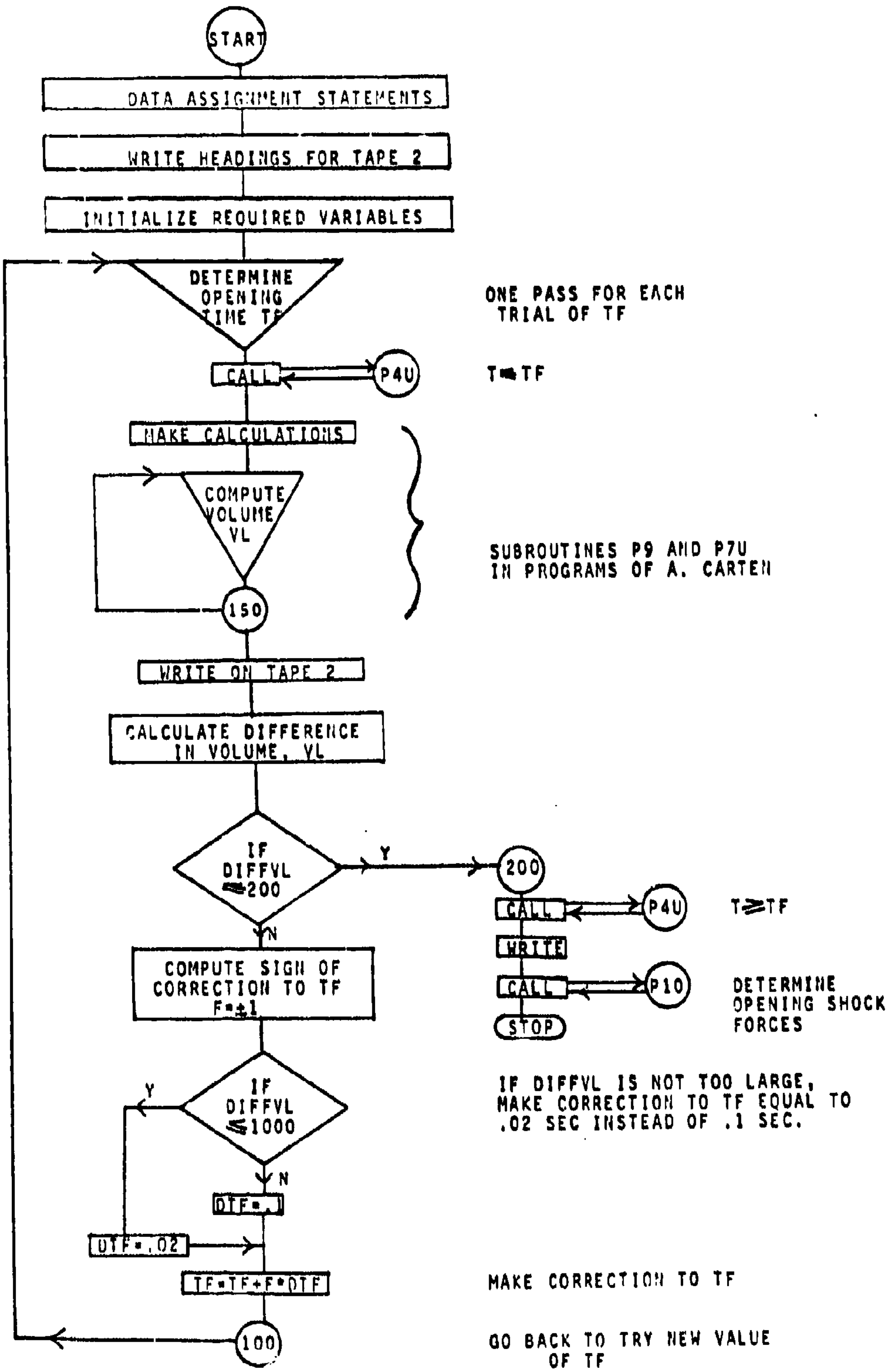
```
      PROGRAM  CHUTE (TAPE1,TAPE2,INPUT,TAPE5=INPUT)
CC
CC    ALBS PARACHUTE DEPLOYMENT CALCULATIONS
CC    WRITTEN FOR A CARTEN, AFGL
CC    BY ROBERT VESPRINI, EMMANUEL COLLEGE, 2/77
CC
      COMMON /VEL/ V(21), DVL(11)
      COMMON /CONST/ PI,G0,D0,TF,CD,W
      DATA PI,G0/3.14159, 32.2/

CC    READ DATA
      READ  (5,*) KMAX, H0, W, TFI, B, CU, D0, CP, V0
      IF (EOF(5).NE.0)  STOP

CC    WRITE HEADINGS FOR TAPE2
      WRITE  (2,20) DATE(TODAY)
      WRITE  (2,22) W,D0,CD,CP
      WRITE  (2,24)

CC    INITIALIZE REQUIRED VARIABLES
      F = 1.  $  TF = TFI
      DTF = .1
      S0 = (PI*D0**2)/4.
      VLMAX = (2./(3.*PI** 3))*D0**3

CC    START CALCULATIONS,ONE VALUE OF TF FOR EACH KOUNT
      DO  100  KOUNT = 1,KMAX
      CALL P4U (0,H0,H,V0,VF1,B)
      VEHI = SQRT(W/(.001189*SIGMA(H0)*CD*S0))

CC    SUBROUTINES P9 AND P7U IN A. CARTEN'S PROGRAMS
      VL = 0.
      C1 = D0**2*TF/PI
      DO  150  J = 1,11
      T = FLOAT(J-1)/10.
      DVL(J) = -C1*V(J)*((1.-T)*T**(4./3.) - 2.*CP*T*(1.-T))
      VL = VL + .1*DVL(J)
150   CONTINUE
      WRITE (2,26) V
      WRITE (2,26) DVL

CC    IS TF ACCEPTABLE?  IF IT IS, GO TO 200.
      DIFFVL = ABS(VLMAX - VL)
      IF (DIFFVL.LE.200.)  GO TO 200
      F = (VLMAX - VL)/DIFFVL
      WRITE (1,10) KOUNT,TF,VLMAX,VL,DIFFVL
      WRITE (2,10) KOUNT,TF,VLMAX,VL,DIFFVL
      IF (DIFFVL.LE.1000.)  DTF = .02
      TF = TF + F*DTF
100   CONTINUE
200   CONTINUE

CC    MAKE CALCULATIONS FOR TIME.GT.TF
      CALL P4U (1,H,HF,VF1,VF,B)

      WRITE (1,11)  TF, VEHI, VLMAX, VL
      WRITE (2,10) KOUNT,TF,VLMAX,VL,DIFFVL

CC    MAKE CALC OF ACC AND FORCES, WHILE CHUTE IS BEING DEPLOYED.
      CALL P10 (H0)

10    FORMAT (1H0,I5,5F10.2)
11    FORMAT (1H0,///,11X,*OPENING TIME  = *,F6.2,8X,*VEHI  = *,F7.2
     1,//,11X,*VOLMAX  = *,F10.2,10X,*CALC VOLUME  = *,F10.2)
20    FORMAT (1H1,*ALBS -- SUPPLEMENTARY INFORMATION*,10X,A10)
22    FORMAT (1H0,10X,*INPUT VARIABLES NOT LISTED ELSEWHERE*,//
     1,* SYSTEM HEIGHT  = *,F5.1,15X,* DIAM OF CHUTE  = *,F8.3,//
     2,* COEFF OF DRAG  = *,F6.3,13X,* C OF POROSITY  = *,F8.3,//)
24    FORMAT (1H0,10X,*OTHER CALCULATED VARIABLES*)
26    FORMAT (1H0,11F10.2)
      STOP
      END
```

```
SUBROUTINE P10          74/74    OPT=1                    FTN 4.5+414        05/12/77  13.12.38

              SUBROUTINE P10 (H)
              COMMON /VEL/ V(21), DVL(11)
              COMMON /CONST/ PI,G0,D0,TF,CD,W
              DIMENSION DVDT(11)

        CC    INITIALIZE REQUIRED VARIABLES
              CDSOM = CD*(PI/4.)*D0**2
              A = (W*100000.)/(SIGMA(H)*G0*D0**3)
              B = 120.*CDSOM/D0**3
              C = A*G0

        CC    WRITE HEADINGS ON TAPE1
              WRITE  (1,1)  DATE(TODAY)

        CC    START CALCULATIONS, INTERVALS OF TF/10.
              DO  100  I = 1,11
              T = FLOAT(I-1)/10.
              DVDT(I) = (22.5*V(I) - 3*TF*T*V(I)**2 + C*TF)/(A + 22.5*T)
              F = -(W/(G0*TF))*DVDT(I)
              F0= F + W
              G = F0/W
        CC    WRITE ONE LINE OF OUTPUT
              WRITE (1,10) T, DVL(I), DVDT(I), F, F0, G
        100   CONTINUE

        CC    WRITE ADDITIONAL INFORMATION
              WRITE (1,20) A, B, C, CDSOM

        1     FORMAT (1H1,10X,*PROGRAM P9*,13X,*PROGRAM P10*,20X,A10,////
             1,19X,*T/TF      DVOL (CUFT) DV/DT (FPS/S)*,10X,*F(LB)*,9X,
             2 *F0(LB)*,7X,*F0/W (G)*,/)
        10    FORMAT (1H0,10X,F8.1,4F19.2,F14.3)
        20    FORMAT (1H0,10X,*A  = *,F12.3,5X,*B  = *,F14.5,5X,*C  = *,F12.3,//
             1,5X,*CDSO  = *,F12.2)
              RETURN
              END
```

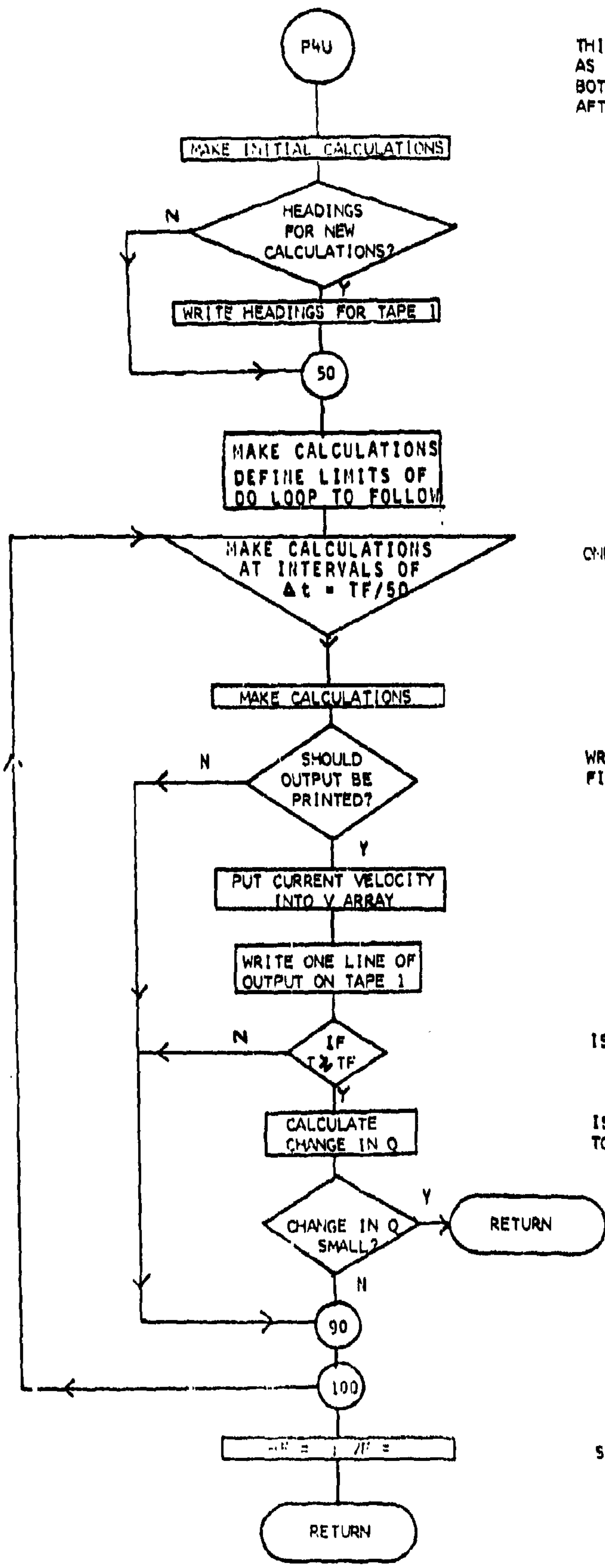
```
FUNCTION SIGMA          74/74    OPT=1                    FTN 4.5+414        05/12/77  13.12.36

              FUNCTION SIGMA (H)
              DIMENSION SIG(25)
        C     THIS FUNCTION INTERPOLATES BETWEEN VALUES OF THE DENSITY RATIO,
        C     GIVEN BY SIG IN INTERVALS OF 1000 FT.
              DATA SIG/.97107,.94278,.91513,.88811,.86170,.83590
             1,.81070,.78609,.76206,.73859,.71568,.69333,.67151
             2,.65022,.62946,.60921,.58946,.57021,.55144,.53315
             3,.51534,.49798,.48108,.46462,.44859/
              J = H/1000.
              XJJ = H - 1000.*FLOAT(J)
              SIGMA = SIG(J) + (SIG(J+1) - SIG(J))*XJJ/1000.
              RETURN
              END
```

```
      SUBROUTINE P4U (IFLAG,H0,HF,V0,VF,B)
CC    IFLAG = 0 --  CHUTE IS BEING DEPLOYED
CC    IFLAG = 1 --  CHUTE HAS BEEN DEPLOYED
      COMMON /CONST/ PI,G0,D0,TF,CD,W
      COMMON /VEL/ V(21),  DVL(11)

CC    INITIALIZE REQUIRED VARIABLES
      S0 = (PI*D0**2)/4.
      Q = .001189*SIGMA(H0)*V0**2

C     WRITE HEADINGS FOR TAPE1, IF NECESSARY.
      IF (IFLAG.EQ.1)  GO TO 50
      WRITE  (1,10) DATE(TODAY)
      WRITE  (1,2) B, Q, V0, H0
   50 CONTINUE

      V(10*IFLAG+1) = VI = V1 = V0
      H = H0
      QI = 0.
      DT = TF/50.
      DV1 = DV0 = -G0*DT*(1. - Q*CD*S0*FLOAT(IFLAG)/W)
      IBB = 50*IFLAG + 1  $  IFF = IBB + 49

CC    START CALCULATIONS, INTERVALS OF DT = TF/50.
      DO  100  I = IBB,IFF
      T = FLOAT(I)/50.
      TIME = T*TF
      A = (S0-B)*AMIN1(T,1.) + B
      DVPRE = 2.*DV1 - DV0
      VPRE = V1 + DVPRE
      VEAV = (V1 + VPRE)/2.
      DHPRE = VEAV*DT
      Q = .001189*SIGMA(H+DHPRE)*VPRE**2
      D = Q*CD*A
      DVI = -G0*DT*(1. - D/W)
      VI = V1 + DVI
      DHI = .5*(VI + V1)*DT
      H = H + DHI
      V1 =VI
      DV0 = DV1
      DV1 = DVI

CC    WRITE ONE LINE OF OUTPUT, EVERY FIFTH CALCULATION
      II = MOD(I,5)
      IF (II.NE.0)  GO TO 90
      IJ = I/5 + 1
      V(IJ) = VI
      WRITE (1,1)A,T,TIME,Q,DVI,VI,D,H

CC    FOR IFLAG = 1, CALC STOPS WHEN DIFF IN Q IS SMALL
      IF (IFLAG.EQ.0)  GO TO 90
      DIFFQ = ABS(Q - QI)
      IF (DIFFQ.LE..001)  RETURN
      QI = Q
   90 CONTINUE

CHECK IF (IFLAG.EQ.1)  WRITE (2,1)  A,T,TIME,Q,DVI,VI,D,H
CHECK WRITE (2,1) A, T, TIME, Q, DVI, VI, D, H
  100 CONTINUE

CC    HF AND VF ARE OUTPUT OF P4U SENT BACK TO ALBS
      HF = H  $  VF = VI
      WRITE (2,2)  B,Q,VF,HF
    1 FORMAT (1H0,10X,F11.2,F8.1,F9.2,2F11.4,3F11.2)
    2 FORMAT (1H ,10X,F11.2,17X,F11.4,11X,2(F11.2,11X))
   10 FORMAT (1H1,10X,*PROGRAM P4U *,A10,////
     1,12X,*AREA(SQFT)     T/TF     T(SEC)        Q(PSF)        DV(FPS)        V(FPS)
     2       D(LB)        H(FT)*,//)
      RETURN
      END
```

PROGRAM CHUTE



SUBROUTINE P4U



THIS SUBROUTINE MAKES CALCULATIONS AS THE CHUTE IS DESCENDING, BOTH WHILE IT IS OPENING AND AFTER IT HAS OPENED.

ONE PASS FOR EACH TIME.

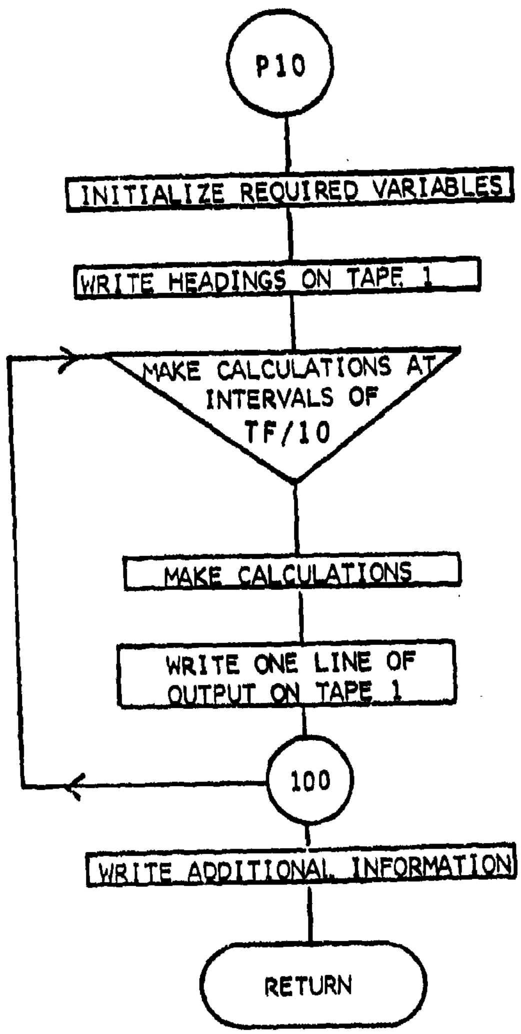
WRITE ONE LINE OF OUTPUT EVERY FIFTH CALCULATION.

IS PARACHUTE FULLY OPENED?

IS VELOCITY SUFFICIENTLY CLOSE TO EQUILIBRIUM VELOCITY (VEHI)?

SET FINAL HEIGHT AND VELOCITY.

SUBROUTINE P10



THIS SUBROUTINE COMPUTES OPENING SHOCK FORCES.

ONE PASS FOR EACH TIME INTERVAL.

end of file

10,23771,1430,3.5,962.11,.755,72.945,.048,-47.62

program

```
PROGRAM CHUTE (TAPE1,TAPE2,INPUT,TAPE5=INPUT)
```

end of record

```
COPY,TAPE2,OUTPUT.
COPY,TAPE1,OUTPUT.
REWIND,TAPE1,TAPE2.
LGO.
LDSET,PRESET=ZERO.
FTN.
VESPA.                                                    2037    MANSFIELD
```

PROGRAM P4U 05/12/77

AREA(SQFT)	T/TF	T(SEC)	Q(PSF)	DV(FPS)	V(FPS)	D(LB)	H(FT)
962.11			1.2629		-47.62		23771.08
1283.81	.1	.35	1.3765	-.1589	-49.65	1334.27	23753.90
1605.50	.2	.70	1.3365	.2996	-48.97	1620.04	23735.58
1927.20	.3	1.05	1.2157	.5342	-46.53	1768.89	23719.81
2248.90	.4	1.40	1.0684	.6053	-43.75	1814.04	23703.37
2570.59	.5	1.75	.9280	.5848	-40.75	1800.98	23689.13
2892.29	.6	2.10	.8073	.5248	-38.01	1762.94	23675.41
3213.99	.7	2.45	.7083	.4552	-35.60	1718.79	23662.54
3535.69	.8	2.80	.6284	.3899	-33.52	1677.35	23650.45
3857.38	.9	3.15	.5637	.3337	-31.74	1641.74	23639.04
4179.08	1.0	3.50	.5110	.2874	-30.22	1512.35	23628.20

1 3.50 26217.80 26451.65 233.64

PROGRAM P4U 05/12/77

AREA(SQFT)	T/TF	T(SEC)	Q(PSF)	DV(FPS)	V(FPS)	D(LB)	H(FT)
952.11			1.2623		-47.62		23771.00
1283.81	.1	.35	1.3760	-.1509	-49.64	1333.73	23754.00
1605.50	.2	.70	1.3364	.2976	-46.97	1619.89	23736.78
1927.20	.3	1.04	1.2161	.5321	-46.70	1769.51	23720.10
2248.90	.4	1.39	1.0692	.6040	-43.77	1815.40	23704.35
2570.59	.5	1.74	.9283	.5842	-40.78	1802.79	23689.65
2892.29	.6	2.09	.8082	.5249	-38.83	1764.98	23675.94
3213.99	.7	2.44	.7091	.4556	-35.62	1720.70	23663.14
3535.69	.8	2.78	.6298	.3984	-33.54	1679.09	23651.11
3857.38	.9	3.13	.5642	.3342	-31.76	1643.27	23639.76
4179.08	1.0	3.48	.5114	.2879	-30.23	1613.69	23628.98
4179.08	1.1	3.83	.4805	.1348	-29.30	1516.01	23618.64
4179.08	1.2	4.18	.4663	.0648	-28.85	1471.37	23608.53
4179.08	1.3	4.52	.4595	.0314	-28.64	1450.61	23598.53
4179.08	1.4	4.87	.4564	.0155	-28.53	1439.90	23588.59
4179.08	1.5	5.22	.4548	.0079	-28.48	1435.07	23578.57
4179.08	1.6	5.57	.4541	.0043	-28.45	1432.76	23568.76

OPENING TIME = 3.48 VEHI = 28.53

VOLMAX = 26217.88 CALC VOLUME = 26310.60

PROGRAM P9 PROGRAM P10 05/12/77

T/TF	DVOL (CUFT)	DV/DT (FPS/S)	F(LB)	FB(LB)	FB/W (G)
0.0	-0.00	68.19	-870.26	559.74	.391
.1	9694.10	29.39	-375.05	1054.95	.738
.2	22572.17	.26	-3.38	1426.62	.998
.3	33143.30	-17.13	218.55	1648.55	1.153
.4	39675.81	-25.39	324.85	1754.85	1.227
.5	41929.29	-28.13	358.96	1788.96	1.251
.6	40212.09	-28.87	358.20	1788.20	1.250
.7	34910.18	-26.84	342.49	1772.49	1.240
.8	26323.58	-25.26	322.33	1752.33	1.225
.9	14647.51	-23.69	302.31	1732.31	1.211
1.0	-0.00	-22.26	284.11	1714.11	1.199

A = 24.428 B = .97349 C = 766.573

COSO = 3155.20

ALBS -- SUPPLEMENTARY INFORMATION 05/12/77

INPUT VARIABLES NOT LISTED ELSEWHERE

SYSTEM WEIGHT = 1433.0 DIAM OF CHUTE = 72.965

COEFF OF DRAG = .755 C OF POROSITY = .040

OTHER CALCULATED VARIABLES

	962.11			.5110		-30.22		23628.20		
-47.62	-49.65	-48.97	-46.69	-43.75	-40.76	-38.01	-35.60	-33.52	-31.74	-30.22
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
-0.00	9751.55	22782.97	33327.70	39000.51	42140.76	40420.35	35891.00	26650.84	14724.62	-0.00
1	3.50	26217.00	26451.65	233.84						
	962.11			.5114		-30.23		23628.30		
-47.62	-49.64	-48.97	-46.70	-43.77	-40.78	-38.03	-35.62	-33.54	-31.76	-30.23
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
-0.00	9694.10	22572.17	33143.30	39675.31	41923.29	40212.09	34310.13	26323.50	14647.51	-0.00
2	3.40	26217.00	26310.00	93.00						

Nomenclature

Program CHUTE

B	Cross-sectional area (b) of parachute at t=0
CD	Coefficient of drag, C_D
CP	Coefficient of porosity, C_P
C1	$(C1) = d_o^2 t_f/\pi$
DIFFVL	Absolute difference between the calculated and theoretical parachute volume
DTF	Correction to t_f to get DIFFVL below an arbitrary limit
DVL	Rate of change (dV/dT) of volume with $T = t/t_f$
DO	Parachute diameter, d_o
F	Number used to decide whether t_f should be increased or decreased to produce an acceptable parachute volume.
GO	Acceleration of gravity ($g_o = 32.2 ft/sec^2$)
H	Final height returned from subroutine P4U
HF	Final height after chute has achieved equilibrium velocity
HO	Initial height, H_i
J	Index used to increment successive iteration
KMAX	Maximum number of different opening times (t_f) that will be tried for a given run. This is an additional safeguard against the program going into infinite loop.

KØUNT	Index used to count the number of different opening times (t_f) that have been tried.
PI	π
SIG	Array defining σ at 1000-ft intervals, where SIG(I) = σ(h=1000*I), up to 25000 ft.
SO	Cross-sectional area (S_o) of parachute when fully opened ($t=t_f$)
T	Fraction of opening time, $T = t/t_f$
TF	Opening time, t_f
TFI	Initial value of opening time, read into the program
TØDAY	Dummy variable used to print date
V	Array containing values of velocity (v), where V(1) = v(T=.1),v(2)=v(T=.2), etc.
VEHI	Equilibrium velocity ($V_{e(Hi)}$) of parachute system
VF	Final velocity, VF=VEHI
VFI	Velocity after parachute is fully opened ($t=t_f$)
VL	Parachute volume calculated using opening time $t=t_f$
VLMAX	Theoretical parachute volume
VO	Initial velocity of parachute system (at t=0)
W	Weight of parachute system, W_s

Nomenclature

Subroutine P4U

A	Cross-sectional area of parachute at a given time t
B	Same as in CHUTE
CD	Same as in CHUTE
D	Drag of parachute, D
DHI	Change in height in time DT=t_f/50
DHPRE	Initial calculation of change in height
DIFFQ	Change in q in time t=.1t_f. This is used only after the chute is fully opened (IFLAG = 1) to determine if the velocity (V) is close enough to the equilibrium velocity (VEHI)
DT	Time increment/iteration; DT = t_f/50
DVI	Change in velocity (V) in time DT
DVL	Same as in CHUTE
DVPRE	Initial calculation of velocity change in time DT
DVO, DVI	Used in determining DVPRE. They are the two previous DVI's
DO, GO	Same as in CHUTE
H	Height
HF	Final height when P4U returns control to CHUTE
HO	Initial height when P4U starts
I	Index used to increment successive iterations

IBB, IFF	Beginning and final values of index I
IFLAG	Index used to tell P4U whether the parachute is in the process of opening (IFLAG = 0, $0 \le t \le t_f$) or is fully opened (IFLAG = 1, $t \ge t_f$)
II	Index to determine whether a particular iteration should be printed. (Only 1 out of 5 is printed)
IJ	Index used to place a velocity value (VI) into the array V; this index corresponds to a time such that V(IJ)=v(T), IJ=10*T+1
PI	Same as in CHUTE
Q	Dynamic pressure, $q = \frac{1}{2}\rho v^2$
QI	Previous value of Q; used to calculate DIFFQ
SO, T, TF	Same as in CHUTE
TIME	Real time t(sec)
TØDAY,V	Same as in CHUTE
VEAV	Average velocity over the interval DT
VF	Final velocity when P4U returns control to CHUTE
VI	New velocity at end of time increment DT
VPRE	Preliminary value of new velocity at end of time increment DT
VO	Initial velocity when P4U starts
VI	Used to store the previous velocity (VI)
W	Same as in CHUTE

Nomenclature

Subroutine P10

A,B,C	Coefficients used to calculate DVDT
CD	Same as in CHUTE
CDSOM	$(C_D S_o)_m = C_D S_o$
DVDT	Acceleration of parachute system (ft/sec^2)
DVL, DO	Same as in CHUTE
F	Force produced by the drag of the parachute (lbs)
FO	Sum of the drag of the parachute and the force of gravity
G	Acceleration in g's corresponding to FO
H	Height at which σ is to be calculated This value $\sigma(H)$ is held constant throughout the subroutine
I	Index used to specify the time (T=.1*I)
PI,T,TF,TØDAY,V,W	Same as in CHUTE

Function SIGMA

H	Height at which SIGMA is to be calculated
J	Index used to determine 1000-ft interval
SIG	Same as in CHUTE
SIGMA	Value of $\sigma(H)$ calculated and returned to calling program or subroutine
XJJ	Variable which is used to interpolate σ between $h=1000J$ and $h=1000(J+1)$

Program P14B

This program treats the ALBS system starting from the point when the balloon has been completely extracted, and the helium has begun to enter the balloon. Calculations are done every 200 ft, as the system descends through the atmosphere, and one line of output is printed for each height. The effect of the system weight, the drags of the drogue and main parachutes, the lift produced by the increasing volume of helium in the balloon, and the change in temperature and pressure of the atmosphere are all taken into account by the program.

Data is introduced to the program thru a READ statement. Each time a card of data is read, another set of calculations is done. Any number of sets of calculations may be done during the execution of the program. In this way, parametric studies of any of the parameters in the READ statement can be done easily. The data must be 'unformatted', i. e., the variables must be separated by commas.

The output of the program is written on tapes 1 and 2 (See Figures 1-4). After the headings are written, one line of output is written for each height (200-ft intervals). Since the values of so many variables are written, the width of one page of computer paper is not enough to write

them all across the page in one line. Hence, for each height, some of the variables are written on tape 1 (Figures 1 and 3) and the rest on tape 2 (Figures 2 and 4). After completion of the job, the pages are separated and each set of calculations is taped together so that the data for a given height can be read across the page in one line.

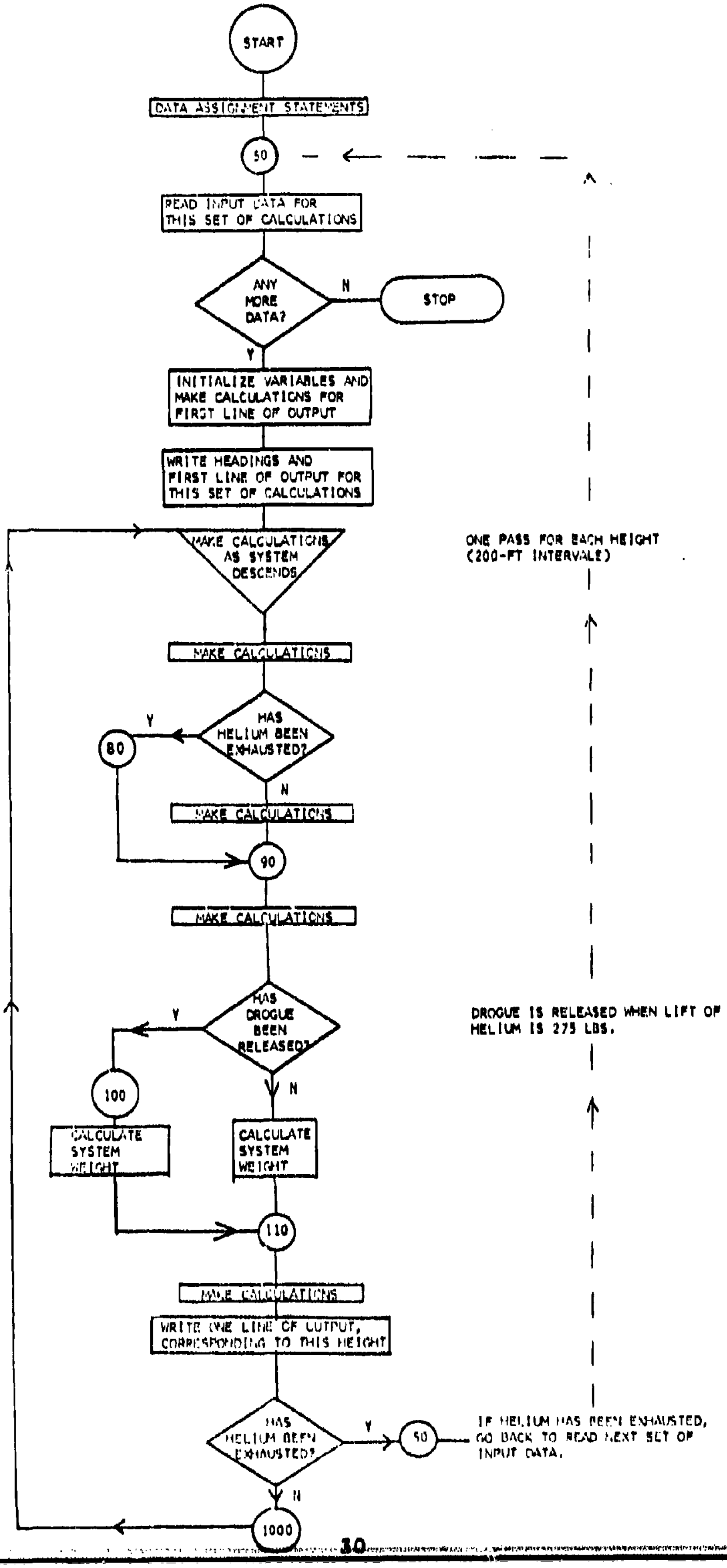
Each time another READ statement is executed, another set of calculations is done. For each new set of calculations, the headings are reprinted at the tops of new pages on tapes 1 and 2.

The Fortran version, explained here, also contains two new features not found in the original version written for the desk-top calculator. The first takes into account the adiabatic heating of the gas in the balloon as the system descends into a denser and denser atmosphere. The second provides an interpolation to determine the exact height at which the helium is exhausted (instead of the height of the nearest 200-ft interval) and the values of the other parameters at that height. These features are explained in detail below.

```
      PROGRAM P148 (TAPE1,TAPE2,INPUT,TAPE5=INPUT)
CC
CC    ALBS BALLOON INFLATION CALCULATIONS
CC    WRITTEN FOR A. CARTEN, AFGL
CC    BY ROBERT VESPRINI, EMMANUEL COLLEGE, 2/77
CC
      DIMENSION PRESS(25), SIG(25)
      DATA PRESS/.9643,.9298,.8962,.8636,.8320,.8014,.7717,.7428,
     1 .7149,.6878,.6616,.6361,.6115,.5876,.5646,.5422,.5206,
     2 .4997,.4795,.4599,.4410,.4227,.4051,.3880,.3716/
      DATA SIG/.97107,.94278,.91513,.88811,.86170,.83590
     1,.81070,.78609,.76206,.73859,.71568,.69333,.67151
     2,.65022,.62946,.60921,.58946,.57021,.55144,.53316
     3,.51534,.49798,.48108,.46462,.44859/
      DATA PI,C1,DH /3.14159,3.0413,-200./
CCCC  READ DATA
50    READ (5,*) HI, WSREF, THE, TR, TREF, V0, DT, TLREL, WD, DAD, DAM
      IF (EOF(5).NE.0)  STOP

CCCC  INITIALIZE REQUIRED VARIABLES
      TMHE = 102.44
      DTEMP = .8  $  TEMP = THE
      IFLAG = 0  $  F = 1.
      ITOP = IFIX(HI/200.) - 1
      IF (ITOP.GT.124)  ITOP = 124
      I = ITOP + 1
      J = I/5
      JJ = I - 5*J
      SIGMA = SIG(J) + (SIG(J+1)-SIG(J))*FLOAT(JJ)/5.
      P = PRESS(J) + (PRESS(J+1)-PRESS(J))*FLOAT(JJ)/5.
      VOL = TM = T = 0.
      DAS = DAD + DAM

CCCC  WRITE HEADINGS AND DATA AT INITIAL HEIGHT
      WRITE (1,10) DATE(TODAY)
      WRITE (1,11) THE,TREF,TR,DT
      WRITE (2,12) DAM, DAD, WD, TLREL
      WRITE (1,1)
      WRITE (2,2)
      WRITE (1,13) HI, SIGMA, P, V0
      WRITE (2,14) HI, WSREF, DAS

CCCC  START CALCULATIONS, 200-FT INTERVALS
      DO  1000  II = 1,ITOP
      I = ITOP - II + 1
      J = I/5
      DM = DT*TR
      TMM = TM + DM

CCCC  HAS HELIUM BEEN EXHAUSTED?  IF NOT, GO TO 80.
      IF (TMM.LT.TMHE)  GO TO 80
      IFLAG = 1
      F = (TMHE-TM)/DM
      TM = TMHE
      GO TO 90
80    TM = TMM
90    CONTINUE
```

```
          H = -DH*(FLOAT(I+1) - F)
          XJJ = -DH*(FLOAT(I - 5*J + 1) - F)
          TAIR = TREF - 2.*(H-HI)/1000.
          SIGMA = SIG(J) + (SIG(J+1) - SIG(J))*XJJ/1000.
          P = PRESS(J) + (PRESS(J+1) - PRESS(J))*XJJ/1000.
          TEMP = ((TM-DM)*(TEMP+DTEMP) + DM*THE) /TM
          RLM = (22.035/TAIR-(C1/TEMP))/(C1/TEMP)
          TL = TM*RLM

    CCCC  HAS THE DROGUE CHUTE BEEN RELEASED?  IF NOT, GO TO 100.
          IF (TL.LT.TLREL)  GO TO 100
          WS = WSREF - TL - WD
          DAD = 0.
          GO TO 110
    100   WS = WSREF - TL
    110   CONTINUE

          VOL = (TM*TEMP)/(C1*P)
          DIAB = ((6./PI)*VOL)**(1./3.)
          DAB = (PI/4.)*DIAB**2 *.5
          DAS = DAB + DAD + DAM
          VE = -SQRT(ABS(WS/(.001189*SIGMA*DAS)))
          VEAV = (VE + V0)/2.
          DT = F*DH/VEAV
          T = T + DT
          V0 = VE
          Q = .001189*SIGMA*VE**2
          DB = DAB*Q $ DD = DAD*Q $ DM = DAM*Q
          DS = DB + DD + DM
          WW = WS - DS

    CCCC  WRITE ONE LINE OF DATA.
          WRITE (1,3)H,SIGMA,P,TAIR,RLM, DT, T, VE, Q, TM, TEMP
          WRITE (2,4) H,TL,WS,VOL,DIAB,DAS,DAB,DB,DD,DM, WW

    CCCC  IF CALCULATIONS ARE DONE, GO BACK TO READ MORE DATA.
          IF (IFLAG.EQ.1)  GO TO 50

    1000  CONTINUE

    1     FORMAT (1H0,* HEIGHT       SIGMA(AIR)   PRESS(ATM)       T(AIR) *,
         17X,*L/M*5X*D(TIME)        TIME     VEL(EQUIL)*7X,1H3,7X,*MASS(HE)*,
         2 *    TEMP(HE)*)
    2     FORMAT (1H0,* HEIGHT        TOTAL LIFT      WT(SYS)    VOL(BALL)*
         1*    DIA(BALL)    (CDS0)SYS    (CDS0)BALL  DRAG(BALL)   *
         2*DRAG(DROG)   DRAG(MAIN)      WS - DS*)
    3     FORMAT (1H0,F7.0,F14.5,F12.4,F12.1,3F12.3,F12.2,F12.4,F12.3,F12.1)
    4     FORMAT (1H0,F7.0,4X,2F12.2,F12.3,6F12.2,F12.3)
    10    FORMAT (1H1,*ALBS BALLOON INFLATION CALCULATIONS*,/,
         1 *0PROGRAM P148*,5X,A10,//)
    11    FORMAT (1H0,15X,*TEMP(HE) FROM DEWER *,3H = ,F7.1,24X,
         1 *TEMP(AIR)              =  *,F7.1,/,
         2 1H0,15X,*TRANSFER RATE*6X,2H= ,F11.4,20X,
         3 *INITIAL D(TIME)      = *,F9.2,///)
    12    FORMAT (1H1,//////,15X,*DRAG AREA MAIN CHUTE = *,F9.2,
         1 22X,*DRAG AREA DROGUE      = *,F9.2,/,
         2 1H0,14X,*WT DROGUE AND HDWRE  = *,F7.0,
         3 24X,*LIFT AT DROGUE REL   = *,F9.2,///)
    13    FORMAT (1H0,F7.0,2X,F12.5,F12.4,48X,F12.2)
    14    FORMAT (1H0,F7.0,16X,F12.2,24X,F12.2,24X,2F12.2)
          STOP
          END
```

PROGRAM P14B



end of file

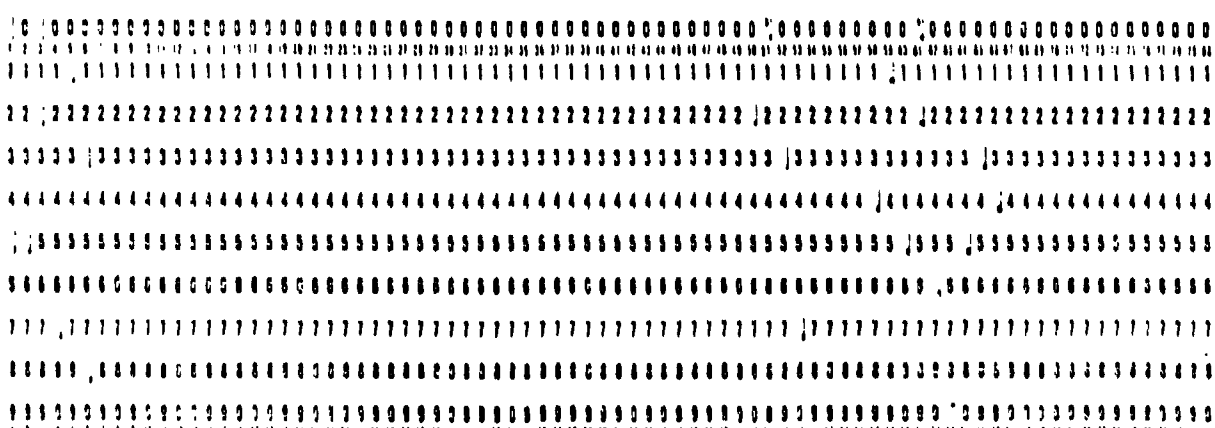
```
22400,1367,260,.3441,260.2,-39.34,5.1,275,66,442.34,1080.65
22400,1367,255,.3441,260.2,-39.34,5.1,275,66,442.34,1080.65
22400,1367,250,.3441,260.2,-39.34,5.1,275,66,442.34,1080.65
```

program

```
      PROGRAM F14B (TAPE1,TAPE2,INPUT,TAPE5=INPUT)
```

end of record

```
COPY,TAPE2,OUTPUT.
COPY,TAPE1,OUTPUT.
REWIND,TAPE1,TAPE2.
LGO.
LDSET,PRESET=ZERO.
FTN.
VEIPA,                                          2037    MANSFIELD
```



ALBS BALLOON INFLATION CALCULATIONS

PROGRAM P148   05/12/77

TEMP(HE) FROM DEWER = 250.0   TEMP(AIR) = 260.2

TRANSFER RATE = .3441   INITIAL D(TIME) = 5.10

HEIGHT	SIGMA(AIR)	PRESS(ATM)	T(AIR)	L/M	D(TIME)	TIME	VEL(EQUIL)	Q	MASS(HE)	TEMP(HE)
22400.	.49122	.4157					-39.34			
22200.	.49453	.4192	260.6	5.951	5.136	5.136	-38.54	.8737	1.755	250.0
22000.	.49798	.4227	261.0	5.951	5.222	10.358	-38.05	.8573	3.522	250.4
21800.	.50145	.4264	261.4	5.951	5.288	15.646	-37.60	.8427	5.319	250.8
21600.	.50492	.4300	261.9	5.952	5.351	20.996	-37.16	.8291	7.139	251.2
21400.	.50840	.4337	262.2	5.952	5.412	26.409	-36.74	.8161	8.980	251.6
21200.	.51187	.4373	262.6	5.952	5.473	31.882	-36.34	.8037	10.842	252.0
21000.	.51534	.4410	263.0	5.952	5.534	37.416	-35.94	.7916	12.726	252.4
20800.	.51890	.4448	263.4	5.952	5.595	43.011	-35.55	.7799	14.630	252.7
20600.	.52247	.4486	263.8	5.952	5.656	48.666	-35.17	.7684	16.555	253.1
20400.	.52603	.4523	264.2	5.952	5.717	54.384	-34.79	.7572	18.501	253.5
20200.	.52950	.4561	264.6	5.952	5.779	60.163	-34.42	.7461	20.468	253.9
20000.	.53316	.4599	265.0	5.952	5.841	66.004	-34.05	.7353	22.457	254.3
19800.	.53682	.4638	265.4	5.952	5.904	71.908	-33.69	.7245	24.467	254.7
19600.	.54047	.4677	265.8	5.952	5.968	77.876	-33.33	.7139	26.498	255.1
19400.	.54413	.4717	266.2	5.952	6.033	83.909	-32.97	.7034	28.552	255.4
19200.	.54778	.4755	266.6	5.952	6.098	90.007	-32.62	.6930	30.628	255.8
19000.	.55144	.4795	267.0	5.952	6.164	96.171	-32.27	.6827	32.726	256.2
18800.	.55513	.4835	267.4	5.952	6.232	102.403	-31.92	.6725	34.847	256.6
18600.	.55895	.4876	267.8	5.951	6.301	108.704	-31.57	.6623	36.992	256.9
18400.	.56273	.4915	268.2	5.951	6.370	115.074	-31.22	.6522	39.160	257.3
18200.	.56646	.4957	268.6	5.951	6.441	121.515	-30.88	.6421	41.352	257.7

18000.	.57021	.4997	269.0	5.950	6.513	128.029	-30.53	.6321	43.568	258.0
17800.	.57436	.5039	269.4	5.950	6.587	134.616	-30.13	.6221	45.610	258.4
17600.	.57791	.5081	269.8	5.949	6.209	140.985	-33.41	.7669	43.076	258.8
17400.	.58176	.5122	270.2	5.949	6.023	146.920	-33.01	.7537	50.240	259.2
17200.	.58561	.5164	270.6	5.953	6.094	153.022	-32.63	.7412	52.313	259.6
17000.	.58946	.5206	271.0	5.950	6.166	159.150	-32.25	.7266	54.410	260.0
16800.	.59341	.5249	271.4	5.951	6.239	165.427	-31.86	.7164	56.532	260.4
16600.	.59736	.5292	271.8	5.951	6.314	171.741	-31.48	.7040	58.678	260.8
16400.	.60131	.5336	272.2	5.951	6.391	178.132	-31.10	.6917	60.851	261.1
16200.	.60526	.5379	272.6	5.951	6.469	184.602	-30.72	.6794	63.050	261.5
16000.	.60921	.5422	273.0	5.951	6.550	191.152	-30.35	.6670	65.276	261.9
15800.	.61326	.5467	273.4	5.951	6.632	197.784	-29.97	.6547	67.530	262.3
15600.	.61731	.5512	273.8	5.950	6.717	204.501	-29.58	.6424	69.812	262.7
15400.	.62136	.5556	274.2	5.950	6.804	211.305	-29.20	.6301	72.124	263.0
15200.	.62541	.5601	274.6	5.949	6.893	218.199	-28.82	.6177	74.465	263.4
15000.	.62946	.5646	275.0	5.949	6.985	225.184	-28.44	.6054	76.837	263.8
14800.	.63361	.5692	275.4	5.948	7.080	232.264	-28.06	.5930	79.241	264.1
14600.	.63776	.5738	275.8	5.948	7.178	239.442	-27.67	.5806	81.677	264.5
14400.	.64192	.5784	276.2	5.947	7.279	246.721	-27.28	.5682	84.147	264.8
14200.	.64607	.5830	276.6	5.946	7.383	254.104	-26.90	.5557	86.651	265.2
14000.	.65022	.5876	277.0	5.945	7.491	261.594	-26.50	.5431	89.192	265.5
13800.	.65440	.5924	277.4	5.944	7.602	269.197	-26.11	.5306	91.769	265.9
13600.	.65874	.5972	277.5	5.943	7.718	276.915	-25.71	.5179	94.385	266.2
13400.	.66239	.6013	278.2	5.941	7.835	284.753	-25.32	.5052	97.041	266.5
13200.	.66725	.6067	278.6	5.940	7.963	292.716	-24.91	.4925	99.736	266.9
13003.	.67145	.6114	279.0	5.939	7.978	300.695	-24.51	.4798	102.440	267.2

DRAG AREA MAIN CHUTE = 1830.55 DRAG AREA DROGUE = 442.34

WT DROGUE AND HOWRE = 66. LIFT AT DROGUE REL = 275.00

HEIGHT	TOTAL LIFT	WT(SYS)	VOL(BALL)	DIA(BALL)	(CDS0)SYS	(CDS0)BALL	DRAG(BALL)	DRAG(DROG)	DRAG(MAIN)	WS - DS
22400.		1367.00			1522.99					
22200.	10.44	1356.56	344.140	8.69	1552.60	29.69	25.34	386.47	944.15	.000
22000.	20.95	1346.04	686.837	10.94	1570.01	47.02	40.31	375.24	926.49	.000
21800.	31.66	1335.34	1028.778	12.52	1584.59	61.60	51.91	372.76	910.67	.000
21600.	42.63	1324.51	1371.078	13.78	1597.60	74.61	61.85	366.73	895.93	0.000
21400.	53.45	1313.55	1712.022	14.84	1609.53	86.54	70.62	361.00	881.93	.000
21200.	64.53	1302.47	2053.941	15.77	1620.67	97.66	76.58	355.49	868.48	.000
21000.	75.74	1291.26	2394.417	16.58	1631.15	108.19	85.65	356.16	855.45	.000
20800.	87.05	1279.92	2733.520	17.35	1641.17	118.18	92.17	344.97	842.78	0.000
20600.	98.54	1268.46	3071.856	18.04	1650.73	127.74	96.16	339.90	830.40	-.000
20400.	110.13	1256.87	3439.446	18.67	1659.93	135.94	103.69	334.93	818.25	.000
20200.	121.84	1245.16	3746.437	19.27	1668.81	145.62	108.00	330.05	806.32	.000
20000.	133.67	1233.33	4092.778	19.83	1677.41	154.42	113.54	325.23	794.56	.000
19800.	145.64	1221.36	4417.276	20.36	1685.73	162.74	117.31	320.49	782.96	.000
19600.	157.73	1209.27	4751.011	20.86	1693.83	170.84	121.37	315.80	771.51	.000
19400.	159.35	1197.05	5084.212	21.33	1701.73	173.74	125.73	311.15	760.17	0.000
19200.	182.38	1184.78	5416.839	21.79	1709.44	166.45	123.22	306.56	748.93	0.000
19000.	194.78	1172.22	5749.145	22.23	1716.99	194.00	132.45	301.59	737.70	.000
18800.	207.40	1159.60	6079.513	22.64	1724.35	201.35	135.41	297.47	726.72	.000
18600.	220.15	1146.85	6409.464	23.05	1731.57	208.58	138.15	292.97	715.73	0.000
18400.	233.04	1133.96	6739.033	23.44	1738.66	215.57	140.56	288.50	704.80	.000
18200.	245.17	1120.93	7068.482	23.81	1745.63	222.64	142.37	284.04	693.32	.000

18000.	259.24	1107.76	7397.712	24.17	1752.50	229.51	145.07	279.61	683.08	0.000
17800.	272.56	1094.64	7726.724	24.53	1759.21	236.22	146.36	275.19	672.30	0.000
17600.	286.02	1014.96	8051.517	24.87	1323.43	242.84	186.23	0.00	828.75	.000
17400.	298.38	1002.10	8357.906	25.10	1329.61	248.96	187.53	0.00	814.47	.000
17200.	311.26	989.74	8645.716	25.46	1335.29	254.64	183.74	0.00	801.36	.000
17000.	323.75	977.24	8933.045	25.74	1340.92	260.27	189.60	0.00	787.56	0.000
16800.	336.40	964.60	9219.037	26.02	1346.44	265.79	190.42	0.00	774.18	.000
16600.	349.19	951.81	9506.122	26.28	1351.92	271.27	190.98	0.00	760.83	0.000
16400.	362.13	938.87	9732.831	26.54	1357.34	276.69	191.35	0.00	747.49	0.000
16200.	375.21	925.79	10030.021	26.80	1362.73	282.08	191.63	0.00	734.15	.000
16000.	388.45	912.55	10367.797	27.05	1368.07	287.42	191.72	0.00	720.83	.000
15800.	401.85	899.15	10653.133	27.30	1373.32	292.67	191.62	0.00	707.53	.000
15600.	415.41	885.59	10939.140	27.54	1378.54	297.89	191.37	0.00	694.22	.000
15400.	429.13	871.87	11225.932	27.78	1383.72	303.07	190.36	0.00	680.90	.000
15200.	443.03	857.97	11513.615	28.02	1388.88	308.23	190.40	0.00	667.57	.000
15000.	457.10	843.90	11802.381	28.25	1394.01	313.36	189.78	0.00	654.20	.000
14800.	471.34	829.66	12089.554	28.48	1399.07	318.42	188.82	0.00	640.83	.000
14600.	485.77	815.23	12377.975	28.70	1404.11	323.46	187.80	0.00	627.42	.000
14400.	500.39	800.61	12667.701	28.92	1409.14	328.49	186.63	0.00	613.97	.000
14200.	515.21	785.79	12958.865	29.14	1414.16	333.51	185.32	0.00	600.47	.000
14000.	530.23	770.77	13251.605	29.36	1419.16	338.51	183.35	0.00	586.92	.066
13800.	545.45	755.55	13544.951	29.57	1424.03	343.44	182.21	0.00	573.34	.000
13600.	560.89	740.11	13834.073	29.78	1429.01	348.36	180.42	0.00	559.69	.000
13400.	576.55	724.45	14128.143	29.99	1433.93	353.28	178.49	0.00	545.97	.000
13200.	592.44	708.56	14424.338	30.20	1438.85	358.20	176.40	0.00	532.17	.000
13000.	608.35	692.65	14713.906	30.41	1443.71	363.06	174.13	0.00	518.40	.000

Nomenclature

Program 14B

C1	=3.0413, used in equation of state (English units)
DAB	Drag area of the balloon, $(C_D S_o)_{balloon}$
DAD	Drag area of the drogue, $(C_D S_o)_{drogue}$
DAM	Drag area of the main chute, $(C_D S_o)_{main}$
DAS	Drag area of the whole system, $(C_D S_o)_{system}$
DB	Drag of the balloon, D_B
DD	Drag of the drogue, D_D
DH	Increment of height, ΔH
DIAB	Diameter of the balloon, d_b
DM	Mass of helium transferred in time, Δt
DS	Drag of the system, D_S
DT	Increment of time, Δt, during which system drops a height ΔH
DTEMP	Increase in temperature, ΔT, of helium due to adiabatic heating from the balloon's dropping a height ΔH (200 ft), DTEMP=.8°/200 ft or 4°/1000 ft
F	Interpolation factor used to calculate last line of output
H	Height, H
HI	Initial height, H_i
IFLAG	Flag used to indicate whether calculations have been completed

NOMENCLATURE

I	Number of intervals of height from ground, i.e., $I = H/\Delta H$
II	Index for DØ loop
ITØP	Number of height intervals of the initial height from the ground, i.e., $ITØP = H_i/\Delta H$
J	Number of height intervals from ground in thousands of feet.
JJ	Number of height intervals from J to I
P	Pressure (P) at height H
PI	π
PRESS	Array containing values of pressure at 1000 ft. intervals, used in the calculation of P
Q	Dynamic pressure, $q = \frac{1}{2}\rho v^2$
RLM	Lift to mass ratio (L/M) of helium in the balloon.
SIG	Array containing values of $\sigma = \rho/\rho_o$ at 1000 ft. intervals, used in the calculation of SIGMA
SIGMA	Ratio of $\sigma = \rho/\rho_o$ at height H
T	Time, t
TAIR	Temperature of the air at height H
TEMP	Temperature of the helium in the balloon at height H
THE	Temperature of helium from the dewer
TL	Total lift at height H

TLREL	Total lift when drogue is to be released.
TM	Total mass at height H
TMHE	Total mass of helium to be transferred to balloon
TMM	Temporary storage for TM
TR	Transfer rate of helium
TREF	Temperature of air at H_i
VE	Equilibrium velocity ($v_e(H_i)$) of system
VEAV	Average velocity over interval
VØL	Volume of the balloon
VO	Velocity at end of preceding interval
WD	Weight of the drogue and associated hardware
WS	Weight of the system less the total lift
WSREF	Initial weight of the system
WW	= (WS - DS) and should always be very close to zero
XJJ	Difference in height from H to next lowest 1000-ft level

Adiabatic Heating of the Gas in the Balloon

As the balloon descends into a thicker and thicker atmosphere, the balloon contracts due to the greater pressure causing the gas in the balloon to undergo a certain amount of adiabatic heating. This is known to be 4°K per 1000 ft of descent and is essentially constant throughout the region of interest.

In program P14B calculations done every 200 ft, and through this distance the gas (already in the balloon, not in the dewer) will heat up by .8°K. The temperature and transfer rate of the gas entering the balloon are assumed to be constant, and the gas in the balloon is assumed to be at all times in equilibrium, i.e., the temperature of the gas is uniform throughout the balloon. The relationship connecting the temperature, pressure, and volume of the gas is taken to be the equation of state for an ideal gas expressed as:

$$V = \frac{mT}{3.0413\ P}$$

where V is in cu ft, m in grams, T in °K, and P in atmospheres.

In each 200-ft interval the system drops a height of 200 ft in a time Δt, which is computed elsewhere in the program. During this time a mass Δm of helium at temperature T_{He} is transferred at a uniform transfer rate r, and we have:

$$\Delta m = r\Delta t$$

Also, the mass m_o of helium already in the balloon is heated .8° from its original temperature T_o to a temperature of $T_o + .8°$. The mass m of helium entering the balloon is at temperature T_{He} and mixes to form a new temperature T inside the balloon such that:

$$T = \frac{m_o(T + .8) + \Delta m T_{He}}{m_o + \Delta m}$$

The new volume of the balloon is:

$$V = \frac{(m + \Delta m)T}{3.0413\ P}$$

where P is the pressure at the new height.

References

1. Carten, Andrew S. Jr., 1976, The Flight Test Aspects of the Air-Launched Balloon System (ALBS) Development Program, AFGL-TR-76-0196.

II. VOR Positioning Program

A. Introduction

The position of a free balloon after launch is found by tracking the balloon from two or more VOR stations which measure the direction of the balloon with respect to magnetic north. The position of the balloon is then found by plotting these bearings on a map of that region.

A program has been written for the HP-9810A programmable calculator which will calculate the balloon position from the station locations and their bearings on the balloon. Calculations are based on spherical geometry, which is exact (for a perfectly spherical earth), and, therefore, errors due to the plotting on the map and to distortions in the projection of the map are eliminated.

The mathematics are described in Section B.

The program stores the coordinates of as many as 8 VOR stations at one time. In this way the path of the balloon can be followed over a longer distance without having to change the station coordinates. The program works as follows:

After the latitudes, longitudes, and declinations of the 8 stations have been input, the program will then request magnetic bearings from any three of those stations. The user will enter the number of each station he has

chosen and its corresponding bearing. Taking the stations two at a time, the program will then calculate intersection points among the three stations selected.

After the coordinates of these intersection points have been calculated and printed, the program will request a new set of bearings. These new bearings need not necessarily be from the same stations previously chosen; any 3 of the 8 may be selected.

A complete description on how to use the program is given in Section C.

B. Mathematics

1. Introduction

The projection on the earth of the line of sight from a VOR station to the balloon follows a great-circle path. Therefore, the balloon position can be found by calculating the location of the point of intersection of the two great circles which correspond to the lines of sight from fixes from the two given VOR stations.

Inputs to the calculation are the latitudes, longitudes, and declinations of the two stations and the directions of the balloon from the stations with respect to magnetic north. The declination is used to change the magnetic direction to a compass heading with respect to true north.

For each station, these quantities are used to form

one vector which points from the station to the balloon, and another vector which points from the center of the earth to the station. Taking the cross product of these two vectors produces a vector which is perpendicular to the plane of that great circle which is the projection of the line of sight from that station to the balloon. In other words, one set of station coordinates and a bearing from that station produces a vector which is normal to the plane of that great circle which corresponds to the line of sight from that station to the balloon.

Taking the cross product of two of these normal vectors produces a vector which points from the center of the earth towards the point of intersection of the corresponding two great circles, i.e., it points along the line of intersection of the two great-circle planes. From this vector one can compute the latitude and longitude of the balloon.

2. Input and Output

The input to the calculation is the latitudes, longitudes, declinations, and magnetic bearings of the balloon of two stations.

The latitudes are north latitudes.

The longitudes are input to and output from the program as west longitudes. However, for mathematical convenience, within the program and in the calculations which follow,

east longitude is used in order to be consistent with a right-handed Cartesian coordinate system.

In the program the magnetic bearings are converted to bearings with respect to true north by adding to each its corresponding declination (expressed as positive for an easterly declination).

The north latitude and west longitude of the balloon position are printed by the program.

3. Nomenclature

O	is the center of the earth
A, C	are two VOR stations
B	is the position of the balloon
$\theta_A, \theta_B, \theta_C$	are the north latitudes of positions A, B, and C, respectively
$\lambda_A, \lambda_B, \lambda_C$	are the east longitudes of positions A, B, and C, respectively
$\vec{OA}$, $\vec{OB}$, $\vec{OC}$	are unit vectors from O to A, B, and C, respectively. These vectors are local verticals
$\vec{AN}$, $\vec{CN}$	are unit vectors at A and B, respectively, which point due north, i.e., these vectors are local horizontals pointing north
$\vec{AE}$, $\vec{CE}$	are unit vectors at A and B, respectively, which point due east. i.e., local horizontals pointing east

η_A, η_B	are bearings on the balloon with respect to true north from stations A and C, respectively
$\vec{AB}$, $\vec{CB}$	are unit vectors which point from A and C, respectively, along those great-circle paths which are in the direction of the balloon B, i.e., local horizontals pointing in the direction of the balloon
$\vec{n}_A, \vec{n}_B$	are vectors which are normal to the great-circle planes specified by the vectors $\vec{AB}$ and $\vec{CB}$, respectively

4. Equations

a. The first step is to form the vectors $\vec{OA}$, $\vec{AN}$, and $\vec{AB}$ for station A. The vectors $\vec{OC}$, $\vec{CN}$, and $\vec{CB}$ will then be constructed in a similar fashion. The vectors are expressed in terms of their x, y, and z components respectively. The origin of this Cartesian coordinate system lies at the center of the earth; the z-axis points towards the north pole; the x and y axes lie in the plane of the equator and point toward the 0° and 90° meridians, respectively.

The x, y, and z components of these vectors can be expressed in terms of the latitude θ_A and longitude λ_A of station A.

Looking at Figures 1 and 2, one can see that the x, y, and z components, respectively, of these vectors are:

$$\vec{OA} = (\cos\theta_A \cos\lambda_A, \cos\theta_A \sin\lambda_A, \sin\theta_A)$$

$$\vec{AN} = (-\sin\theta_A \cos\lambda_A, -\sin\theta_A \sin\lambda_A, \cos\theta_A)$$

$$\vec{AE} = (-\sin\lambda_A, \cos\lambda_A, 0)$$

The vectors $\vec{OC}$, $\vec{CN}$, and $\vec{CE}$ are constructed similiarly, and their components can be found by substituting θ_C for θ_A and λ_C for λ_A in the vectors given above.

b. The next step is to form the vector $\vec{AB}$ which points from A along the great-circle path which is the projection of the line of sight from A to B. In Figure 3 is a diagram of the local horizontal plane at A. From this we see that:

$$\vec{AB} = \vec{AN} \cos\eta_A + \vec{AE} \sin\eta_A$$

Expanding this to find the x, y, and z components of $\vec{AB}$, we have:

$$\begin{aligned}\vec{AB} = (&-\sin\theta_A \cos\lambda_A \cos\eta_A - \sin\lambda_A \sin\eta_A,\\ &-\sin\theta_A \sin\lambda_A \cos\eta_A + \cos\lambda_A \sin\eta_A,\\ &\cos\theta_A \cos\eta_A)\end{aligned}$$

The vector $\vec{CB}$ is constructed similiarly, and its components can be found by substituting θ_C for θ_A, λ_C for λ_A and η_C for η_A in the above equations.

c. The next step is to form the vector $\vec{n}_A$ which is normal to that great-circle plane which contains the line of sight from station A to balloon B. This vector can be formed by crossing any two vectors which lie in the plane (and are not parallel). The vectors $\vec{OA}$ and $\vec{AB}$ lie in this plane, and we have:

$$\vec{n}_A = \vec{OA} \times \vec{AB}$$

$$(\vec{n}_A)_x = (\vec{OA})_y\ (\vec{AB})_z - (\vec{OA})_z\ (\vec{AB})_y$$

$$= \sin\lambda_A\ \cos\eta_A - \sin\theta_A\ \cos\lambda_A\ \sin\eta_A$$

$$(\vec{n}_A)_y = (\vec{OA})_z\ (\vec{AB})_x - (\vec{OA})_x\ (\vec{AB})_z$$

$$= -\cos\lambda_A\ \cos\eta_A - \sin\theta_A\ \sin\lambda_A\ \sin\eta_A$$

$$(\vec{n}_A)_z = (\vec{OA})_x\ (\vec{AB})_y - (\vec{OA})_y\ (\vec{AB})_x$$

$$= \cos\theta_A\ \sin\eta_A$$

The vector $\vec{n}_B$ is constructed similiarly, and its components can be found by substituting θ_C for θ_A, λ_C for λ_A and η_C for η_A in the above equations.

d. Taking the cross product $\vec{v}$ of the vectors $\vec{n}_A$ and $\vec{n}_B$ produces a vector which points along the line of intersection of the two great-circle planes. This line of intersection passes through the center of the earth and the balloon. The vector formed will point either from the center of the earth to the balloon towards a north latitude or in the opposite direction towards a south latitude. The components of $\vec{v}$ are:

$$v_x = (\vec{n}_A)_y\ (\vec{n}_B)_z - (\vec{n}_A)_z\ (\vec{n}_B)_y$$

$$v_y = (\vec{n}_A)_z\ (\vec{n}_B)_x - (\vec{n}_A)_x\ (\vec{n}_B)_z$$

$$v_z = (\vec{n}_A)_x\ (\vec{n}_B)_y - (\vec{n}_A)_y\ (\vec{n}_B)_x$$

In the case that $\vec{v}$ points towards a south latitude, we can turn the vector around by making the transformation $\vec{v} \rightarrow -\vec{v}$.

e. Even though $\vec{v}$ now points in the direction of $\vec{OB}$, it is not necessarily a unit vector. To form the unit vector,

$\vec{v}$ must be divided by its length and we have:

$$\overrightarrow{OB} = \vec{v} \,/\, |\vec{v}|$$

where $|\vec{v}| = \sqrt{v_x^2 + v_y^2 + v_z^2}$

6) Looking back at Figures 1 and 2, the coordinates of the balloon θ_B and λ_B can be found from $\overrightarrow{OB}$ or $\vec{v}$ by:

$$\theta_B = \sin^{-1}[(\overrightarrow{OB})_z] = \sin^{-1}\left(\frac{v_z}{|\vec{v}|}\right)$$

$$\lambda_B = \cos^{-1}\left[\frac{(\overrightarrow{OB})_x}{\cos\theta_B}\right] = \cos^{-1}\left[\frac{v_x}{|\vec{v}|\cos\theta_B}\right]$$

C. The Program

1. Introduction

The following is a step-by-step description of how to use the VOR positioning program. A sample output, a listing, a flow chart, and an explanation of the organization of the memory are also provided in Figures 4 - 7, respectively. Supplementary information about the program is given which enables the user, when data has been entered incorrectly, to correct the mistake without having to go back to the beginning of the program.

2. How to Use the Program

Press END, CONTINUE.

The program then asks for the number of stations to be put into the calculator. The program can handle up to 8 stations. The user puts this number into the x register and then presses CONTINUE.

The program then prints a station number, starting at station 1 and going up to the number of stations requested

in the previous step, and requests the latitude, longitude, and declination, respectively, of that station. For each of these variables, enter the number of degrees in z, minutes in y, and seconds in x, and then press CONTINUE.

Latitude is input as north latitude, longitude as west longitude, and declination is input as a positive quantity for an easterly declination and as a negative quantity for a westerly declination.

After reading these quantities for a particular station, the program goes on to the next station, or, if the last station has just been input, it goes on to the next step.

The program then asks for the time of day. This is done so that there will be a record of the time that the VOR readings were taken. The user puts the time into the x register in the following way: 14:45 is put in as 14.45, etc. The user then presses CONTINUE.

The program then asks for bearings from any three of the stations, called 1ST, 2ND, and 3RD stations, respectively. For each of the three stations to be selected, enter the number of the station required in the y register and its corresponding magnetic bearing, expressed in decimal degrees, in the x register.

The program then prints the coordinates of the balloon location calculated using the 1st and 2nd stations, then the 1st and 3rd stations, and finally the 2nd and 3rd stations. For each station pair the latitude and longitude

are printed in degrees, minutes, and seconds.

The program then asks for a new time and then new station numbers and bearings. Again, any three stations may be selected, and these need not be the same ones which were selected previously. After each set of bearings has been input, and the balloon positions calculated, the program goes back to ask for a new time and a new set of station numbers and bearings.

A sample output is shown in Figure 4. All variables which the user must supply have an asterisk placed beside them. Note that all variables input by the user are printed on the paper tape immediately after being entered.

3. Supplementary Information

In order to help the user understand (and possibly modify) the program, a listing of the program is given in Figure 5 and a flow chart in Figure 6.

In the case that, after the station data have been entered, it is discovered that a station coordinate was entered incorrectly, or it is necessary that another station be substituted or added, it is usually more convenient to be able to enter the information directly into the memory rather than having the program do it. (For the program to do this requires that all of the

information be reentered.) This requires a better knowledge of the memory and program organization. The organization of the memory is shown in Figure 7.

To put a number into a particular memory location, put the number into the x register, press x→(XTO) followed by the three-digit memory location. Since the coordinates entered in this program are always expressed in terms of degrees, minutes, and seconds, the user must first change this to decimal degrees before entering it into memory. In this case, put the numbers of degrees, minutes, and seconds into the z, y, and x registers, respectively, press K, 6 to convert to decimal degrees in the x register, and then press x→, followed by the three-digit memory address.

For station number i, i = 1 to 8, the latitude θ, longitude λ, and declination η are put into memory locations 5i+5, 5i+6, and 5i+7, respectively. The number of stations which are being stored in the memory is kept in memory address 000.

If a bearing is entered incorrectly, press GTO, 0, 2, 5, 0, and CONTINUE. The program will then ask for a time followed by three new station numbers and their corresponding bearings. The old station numbers and bearing are replaced.

D. Comparison of VOR Data with Radar Data

Using data from a particular balloon flight for which both VOR and radar data were available, a comparison of results using these two sets of data was made. Radar data are considered to produce substantially more accurate results than VOR data and, therefore, are suitable for determining the accuracy of the VOR data.

Errors in VOR positioning can result from a number of sources: 1) the error ($\Delta\eta$) in the magnetic bearing (η) of the target as viewed by the VOR station in question, 2) interference from other radio signals or mountains, and 3) the line of sight being too close to the horizon. The error in the bearing is the only type of error which will be discussed here. Errors due to the other two sources are highly unpredictable and would probably have to be measured empirically.

The error in positioning (E) due to one VOR station alone at a distance d from the target, assuming the bearing of the other station used for the fix is exact, is: $E = d \tan(\Delta\eta)$, or for small $\Delta\eta$, $E = d(\Delta\eta)$. The maximum error in a VOR bearing is known to be $\pm$ 1/2°. Errors ($\vec{E}_1$ and $\vec{E}_2$), due to the errors in the bearings of both of the VOR stations used to produce a given fix, add vectorially to produce the total error $\vec{E} = \vec{E}_1 + \vec{E}_2$. This is shown in Figure 8.

When the angle α, the angle between the lines of sight from two given VOR stations, approaches 180°, i.e., when the balloon is very close to the line joining the two VOR stations, the total error $(\vec{E}_1 + \vec{E}_2)$ can become very large even though the bearings themselves are accurate, i.e., $\Delta\eta_1$ and $\Delta\eta_2$ are small. Conversely, an intersection angle of 90° between the lines of sight is optimum. This is shown in Figure 9. The shaded areas show where the balloon might be for each of the two fixes A and B, assuming an error of $\pm$ 1/2° in each of the bearing-angle measurements. The centers of the shaded areas are the positions where the VOR predicts that the balloon is located. Note that for position B the fact that α is close to 180° can lead to a large error in the prediction of the balloon position.

Both radar and VOR data were available on balloon flight H75-4, which took place on February 7, 1975. VOR data were available from the following stations: 1) Truth or Consequences, 2) Deming, 3) Newman, Texas, 4) Holloman, 5) Pinon, 6) Hudspeth, Texas, 7) Roswell, and 8) Pecos, Texas. These stations and the position of the radar are shown on a map of the area in Figure 10. Balloon positions and their corresponding times are shown throughout the flight.

During this flight balloon positions were computed using Truth or Consequences, Holloman, Pinon, and Roswell. The other stations were too far away to provide accurate results.

Since E = d tan $\Delta\eta$, the error is proportional to the distance of the station from the target. Furthermore, the farther away the station is from the balloon, the closer to the horizon the balloon appears.

Larger discrepancies (2 to 4 nm) occurred at the beginning of the flight (before 9:14) when the balloon had not yet reached flight altitude and was therefore too close to the horizon to get a good fix. The radar was much closer to the balloon during this time, and its results are probably accurate.

Later in the flight (10:35 and after), discrepancies of 2 to 5 nm were seen. At this point the balloon was about halfway between Roswell and Pinon, so that α was close to 180°. Therefore, these two stations could not be used together to get a good fix. Holloman and Truth or Consequences were at this time quite far away (60 and 120 nm, respectively) and were also looking over a mountain range. Hence, using either one of these with either Roswell or Pinon also tended to produce larger errors than usual because of both the distance, increasing the error and making the balloon appear close to the horizon, and the interference produced by the mountains. This seems to have been in fact the case, because the fixes using Holloman were consistently about 3 nm to the south, whereas the fixes using Truth or Consequences were consistently about 3 nm to the north. Note

that the radar data could also have been influenced by the mountains and the balloon's being too close to the horizon. However, the fact that Holloman predicted positions were consistently 6 nm south of those predicted by Truth or Consequences shows that the VOR data themselves were inconsistent. During this part of the flight Carlsbad could have provided a good fix, but data from it were not available.

LIST OF FIGURES

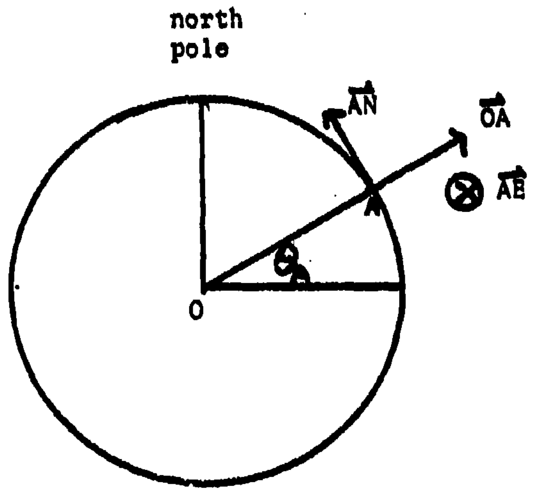


Figure 1. Cross Section of the Earth Containing Points O, A, and the North Pole.

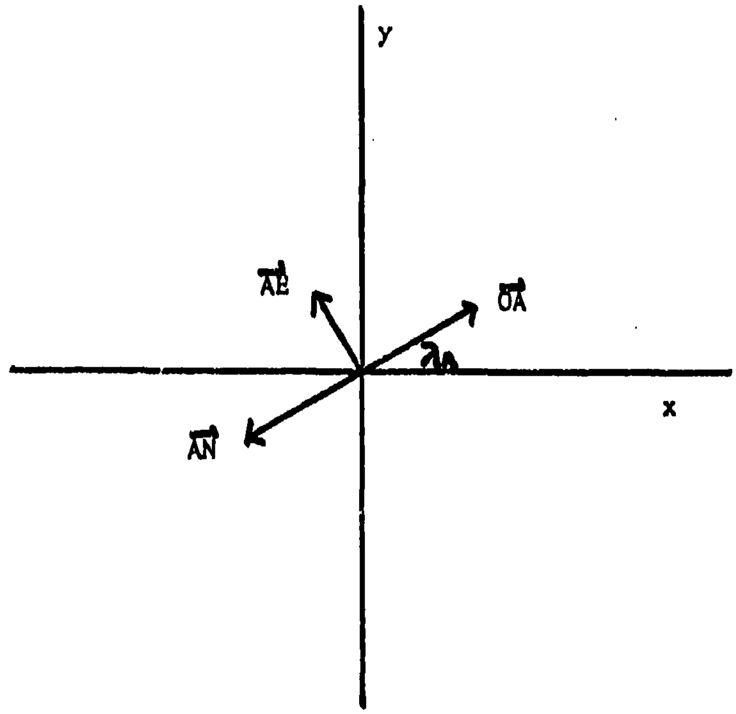
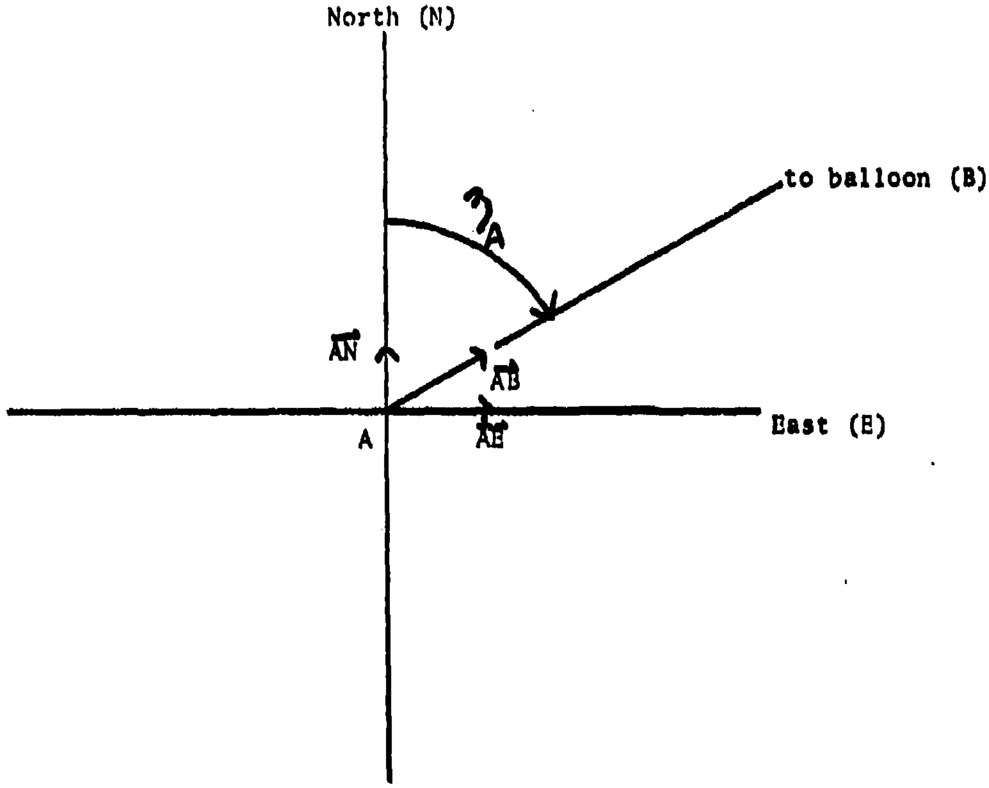


Figure 2. Projections of $\vec{AN}$, $\vec{AE}$, and $\vec{OA}$ in the Plane of the Equator.



$$\vec{AB} = \vec{AN}\cos\eta_A + \vec{AE}\sin\eta_A$$

Figure 3. Vectors in the Plane Tangent to the Earth at A.

Fig.4 Sample output

```
DEGREES
MINUTES
SECONDS

# OF STATIONS
        3.0000*

STATION
        1.0000
LATITUDE
       32.0000*
       59.0000*
       26.0000*

LONGITUDE
      106.0000*
        7.0000*
       50.0000*

DECLINATION
       12.0000*
       15.0000*
        0.0000*

STATION
        2.0000
LATITUDE
       32.0000
       31.0000
       45.0000

LONGITUDE
      105.0000
       18.0000
       17.0000

DECLINATION
       11.0000
       40.0000
        0.0000

STATION
        3.0000
LATITUDE
       32.0000
       20.0000
       15.0000

LONGITUDE
      104.0000
       37.0000
       15.0000

DECLINATION
       11.0000
       51.0000
        0.0000
```

```
TIME
       11.1000*

BEARINGS

1ST STATION
        1.0000*
       90.0000*

2ND STATION
        2.0000*
       33.0000*

3RD STATION
        3.0000*
      201.0000*
```

```
BALLOON POS.

1ST AND 2ND

LATITUDE
       32.0000
       46.0000
        0.8620

LONGITUDE
      105.0000
        1.0000
       24.9361

1ST AND 3RD

LATITUDE
       32.0000
       46.0000
       22.3124

LONGITUDE
      105.0000
        3.0000
       16.8366

2ND AND 3RD

LATITUDE
       32.0000
       40.0000
       58.4405

LONGITUDE
      105.0000
        7.0000
       23.4725

TIME
```

BEST AVAILABLE COPY

PAGE ______ OF ______

PROGRAM NAME ______________________ NUMBER ______________

STEP	KEY	STEP	KEY	STEP	KEY	STEP	KEY	STEP	KEY	STEP	KEY
0000	CLR	0050	FMT	0100	LBL	0150	O	0200	LBL	0250	FMT
0001	CNT	0051	CNT	0101	1	0151	N	0201	A	0251	FMT
0002	CNT	0052	CNT	0102	CNT	0152	G	0202	CNT	0252	CLR
0003	CNT	0053	STP	0103	CNT	0153	I	0203	CNT	0253	CLR
0004	CNT	0054	PNT	0104	FMT	0154	XTO	0204	RUP	0254	CLR
0005	CNT	0055	PNT	0105	FMT	0155	1/X	0205	PNT	0255	XTO
0006	CNT	0056	PNT	0106	YTO	0156	D	0206	RUP	0256	I
0007	CNT	0057	XTO	0107	XTO	0157	E	0207	PNT	0257	M
0008	CNT	0058	0	0108	A	0158	FMT	0208	RUP	0258	E
0009	CNT	0059	0	0109	XTO	0159	CNT	0209	PNT	0259	FMT
0010	FMT	0060	0	0110	I	0160	CNT	0210	PNT	0260	STP
0011	FMT	0061	CNT	0111	O	0161	STP	0211	CNT	0261	PNT
0012	D	0062	1	0112	N	0162	CNT	0212	CNT	0262	PNT
0013	E	0063	XTO	0113	FMT	0163	CNT	0213	K	0263	CLR
0014	G	0064	a	0114	CNT	0164	GTO	0214	6	0264	FMT
0015	a	0065	CNT	0115	CNT	0165	S/R	0215	CNT	0265	FMT
0016	E	0066	CNT	0116	a	0166	LBL	0216	CNT	0266	B
0017	E	0067	CNT	0117	PNT	0167	A	0217	CNT	0267	E
0018	YTO	0068	CNT	0118	UP	0168	CNT	0218	CNT	0268	A
0019	CLR	0069	CNT	0119	5	0169	CNT	0219	CNT	0269	a
0020	M	0070	GTO	0120	X	0170	FMT	0220	CNT	0270	I
0021	I	0071	S/R	0121	+	0171	FMT	0221	CNT	0271	N
0022	N	0072	LBL	0122	YTO	0172	D	0222	CNT	0272	G
0023	1/X	0073	1	0123	b	0173	E	0223	CNT	0273	YTO
0024	XTO	0074	CNT	0124	CNT	0174	C	0224	XTO	0274	CLR
0025	E	0075	CNT	0125	FMT	0175	L	0225	IND	0275	CLR
0026	YTO	0076	a	0126	FMT	0176	I	0226	b	0276	1
0027	CLR	0077	UP	0127	L	0177	N	0227	CNT	0277	YTO
0028	YTO	0078	1	0128	A	0178	A	0228	1	0278	XTO
0029	E	0079	+	0129	XTO	0179	XTO	0229	XTO	0279	CNT
0030	C	0080	XFR	0130	I	0180	I	0230	+	0280	YTO
0031	O	0081	0	0131	XTO	0181	O	0231	b	0281	XTO
0032	N	0082	0	0132	1/X	0182	N	0232	CNT	0282	A
0033	D	0083	0	0133	D	0183	FMT	0233	CNT	0283	XTO
0034	YTO	0084	CNT	0134	E	0184	CNT	0234	S/R	0284	I
0035	CLR	0085	XKY	0135	FMT	0185	CNT	0235	0	0285	O
0036	CLR	0086	0	0136	CNT	0186	STP	0236	0	0286	N
0037	GTO	0087	2	0137	CNT	0187	CNT	0237	0	0287	FMT
0038	CNT	0088	5	0138	STP	0188	CNT	0238	0	0288	CNT
0039	O	0089	0	0139	CNT	0189	GTO	0239	0	0289	CNT
0040	F	0090	CNT	0140	CNT	0190	S/R	0240	0	0290	1
0041	CNT	0091	YTO	0141	GTO	0191	LBL	0241	0	0291	XTO
0042	YTO	0092	a	0142	S/R	0192	A	0242	0	0292	U
0043	XTO	0093	CNT	0143	LBL	0193	CNT	0243	0	0293	0
0044	A	0094	GTO	0144	A	0194	CNT	0244	0	0294	S
0045	XTO	0095	0	0145	CNT	0195	S/R	0245	0	0295	GTO
0046	L	0096	0	0146	CNT	0196	CNT	0246	0	0296	S/R
0047	O	0097	7	0147	FMT	0197	CNT	0247	0	0297	LBL
0048	N	0098	0	0148	FMT	0198	CNT	0248	0	0298	2
0049	YTO	0099	CNT	0149	L	0199	CNT	0249	0	0299	CNT

Fig. 5.1

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STEP	KEY	STEP	KEY	STEP	KEY	STEP	KEY	STEP	KEY	STEP	KEY
0300	FMT	0350	5	0400	CLR	0450	CNT	0500	FMT	0550	0
0301	FMT	0351	CNT	0401	CNT	0451	CNT	0501	FMT	0551	0
0302	2	0352	CNT	0402	FMT	0452	CNT	0502	CLR	0552	0
0303	N	0353	GTO	0403	FMT	0453	CNT	0503	2	0553	0
0304	D	0354	S/R	0404	CLR	0454	CNT	0504	N	0554	0
0305	CNT	0355	LBL	0405	B	0455	CNT	0505	D	0555	0
0306	YTO	0356	2	0406	A	0456	CNT	0506	CNT	0556	0
0307	XTO	0357	CNT	0407	L	0457	CNT	0507	A	0557	0
0308	A	0358	CNT	0408	L	0458	CNT	0508	N	0558	0
0309	XTO	0359	CNT	0409	O	0459	CNT	0509	D	0559	0
0310	I	0360	CNT	0410	O	0460	FMT	0510	CNT	0560	0
0311	O	0361	CNT	0411	N	0461	FMT	0511	3	0561	0
0312	N	0362	CNT	0412	CNT	0462	CLR	0512	α	0562	0
0313	FMT	0363	CNT	0413	π	0463	1	0513	D	0563	0
0314	CNT	0364	CNT	0414	0	0464	YTO	0514	CLR	0564	0
0315	CNT	0365	CNT	0415	YTO	0465	XTO	0515	CLR	0565	0
0316	2	0366	CNT	0416	.	0466	CNT	0516	FMT	0566	0
0317	XTO	0367	CNT	0417	CLR	0467	A	0517	CNT	0567	0
0318	0	0368	CNT	0418	CLR	0468	N	0518	CNT	0568	0
0319	0	0369	CNT	0419	1	0469	D	0519	CNT	0569	0
0320	5	0370	CNT	0420	YTO	0470	CNT	0520	2	0570	0
0321	CNT	0371	CNT	0421	XTO	0471	3	0521	UP	0571	0
0322	CNT	0372	CNT	0422	CNT	0472	α	0522	3	0572	0
0323	GTO	0373	CNT	0423	A	0473	D	0523	CNT	0573	0
0324	S/R	0374	CNT	0424	N	0474	CLR	0524	CNT	0574	0
0325	LBL	0375	CNT	0425	D	0475	CLR	0525	GTO	0575	0
0326	2	0376	CNT	0426	CNT	0476	FMT	0526	S/R	0576	0
0327	CNT	0377	CNT	0427	2	0477	CNT	0527	LBL	0577	0
0328	CNT	0378	CNT	0428	N	0478	CNT	0528	4	0578	0
0329	CNT	0379	CNT	0429	D	0479	CNT	0529	CNT	0579	0
0330	FMT	0380	CNT	0430	CLR	0480	CNT	0530	CNT	0580	0
0331	FMT	0381	CNT	0431	CLR	0481	CNT	0531	CNT	0581	0
0332	3	0382	CNT	0432	FMT	0482	CNT	0532	CNT	0582	0
0333	α	0383	CNT	0433	CNT	0483	CNT	0533	CNT	0583	0
0334	D	0384	CNT	0434	CNT	0484	CNT	0534	CNT	0584	0
0335	CNT	0385	CNT	0435	CNT	0485	1	0535	CNT	0585	0
0336	YTO	0386	CNT	0436	CNT	0486	UP	0536	CNT	0586	0
0337	XTO	0387	CNT	0437	CNT	0487	3	0537	CNT	0587	0
0338	A	0388	CNT	0438	CNT	0488	GTO	0538	CNT	0588	0
0339	XTO	0389	CNT	0439	1	0489	S/R	0539	CNT	0589	0
0340	I	0390	CNT	0440	UP	0490	LBL	0540	GTO	0590	0
0341	O	0391	CNT	0441	2	0491	4	0541	0	0591	0
0342	N	0392	CNT	0442	CNT	0492	CNT	0542	2	0592	0
0343	FMT	0393	CNT	0443	GTO	0493	CNT	0543	5	0593	0
0344	CNT	0394	CNT	0444	S/R	0494	CNT	0544	0	0594	0
0345	CNT	0395	CNT	0445	LBL	0495	CNT	0545	CNT	0595	0
0346	3	0396	CNT	0446	4	0496	CNT	0546	CNT	0596	0
0347	XTO	0397	CNT	0447	CNT	0497	CNT	0547	CNT	0597	0
0348	0	0398	CNT	0448	CNT	0498	CNT	0548	CNT	0598	0
0349	0	0399	CNT	0449	CNT	0499	CNT	0549	CNT	0599	0

Fig. 5.2

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STEP	KEY	STEP	KEY	STEP	KEY	STEP	KEY	STEP	KEY	STEP	KEY
0600	LBL	0650	CHS	0700	XFR	0750	CNT	0800	CNT	0850	0
0601	[illegible]	0651	UP	0701	0	0751	CNT	0801	CNT	0851	0
0602	GTO	0652	3	0702	0	0752	1	0802	DN	0852	0
0603	YTO	0653	6	0703	8	0753	XTO	0803	+	0853	0
0604	IND	0654	0	0704	N	0754	+	0804	CNT	0854	0
0605	0	0655	+	0705	UP	0755	α	0805	CNT	0855	0
0606	0	0656	DN	0706	CNT	0756	CNT	0806	DN	0856	0
0607	5	0657	CNT	0707	CNT	0757	CNT	0807	CNT	0857	0
0608	CNT	0658	CNT	0708	XFR	0758	CNT	0808	CNT	0858	0
0609	CNT	0659	CNT	0709	0	0759	CNT	0809	CNT	0859	0
0610	KEY	0660	XTO	0710	0	0760	XFR	0810	XTO	0860	0
0611	PNT	0661	0	0711	7	0761	0	0811	IND	0861	0
0612	KEY	0662	0	0712	M	0762	0	0812	α	0862	0
0613	PNT	0663	7	0713	X	0763	7	0813	CNT	0863	0
0614	PNT	0664	CNT	0714	CNT	0764	N	0814	CNT	0864	0
0615	KEY	0665	CNT	0715	CNT	0765	CHS	0815	1	0865	0
0616	CNT	0666	1	0716	XFR	0766	UP	0816	XTO	0866	0
0617	UP	0667	XTO	0717	0	0767	CNT	0817	+	0867	0
0618	5	0668	-	0718	0	0768	CNT	0818	α	0868	0
0619	[illegible]	0669	α	0719	6	0769	XFR	0819	CNT	0869	0
0620	7	0670	XFR	0720	M	0770	0	0820	CNT	0870	0
0621	[illegible]	0671	IND	0721	CHS	0771	0	0821	CNT	0871	0
0622	CNT	0672	α	0722	UP	0772	8	0822	CNT	0872	0
0623	CNT	0673	CNT	0723	CNT	0773	N	0823	CNT	0873	0
0624	YTO	0674	CNT	0724	CNT	0774	X	0824	CNT	0874	0
0625	α	0675	CNT	0725	XFR	0775	CNT	0825	XFR	0875	0
0626	XFR	0676	XTO	0726	0	0776	CNT	0826	0	0876	0
0627	IND	0677	0	0727	0	0777	XFR	0827	0	0877	0
0628	α	0678	0	0728	7	0778	0	0828	6	0878	0
0629	CNT	0679	6	0729	N	0779	0	0829	N	0879	0
0630	CNT	0680	XFR	0730	X	0780	6	0830	UP	0880	0
0631	RUP	0681	0	0731	CNT	0781	M	0831	CNT	0881	0
0632	+	0682	0	0732	CNT	0782	CHS	0832	CNT	0882	0
0633	DN	0683	5	0733	XFR	0783	UP	0833	XFR	0883	0
0634	CNT	0684	CNT	0734	0	0784	CNT	0834	0	0884	0
0635	XTO	0685	CNT	0735	0	0785	CNT	0835	0	0885	0
0636	0	0686	UP	0736	8	0786	XFR	0836	8	0886	0
0637	CNT	0687	1	0737	M	0787	0	0837	M	0887	0
0638	CNT	0688	-	0738	X	0788	0	0838	X	0888	0
0639	1	0689	3	0739	CNT	0789	7	0839	CNT	0889	0
0640	XTO	0690	X	0740	CNT	0790	M	0840	CNT	0890	0
0641	-	0691	5	0741	DN	0791	X	0841	DN	0891	0
0642	α	0692	1	0742	+	0792	CNT	0842	CNT	0892	0
0643	CNT	0693	+	0743	CNT	0793	CNT	0843	CNT	0893	0
0644	CNT	0694	CNT	0744	CNT	0794	XFR	0844	CNT	0894	0
0645	XFR	0695	CNT	0745	DN	0795	0	0845	CNT	0895	0
0646	IND	0696	YTO	0746	CNT	0796	0	0846	XTO	0896	0
0647	α	0697	α	0747	XTO	0797	8	0847	IND	0897	0
0648	CNT	0698	CNT	0748	IND	0798	M	0848	α	0898	0
0649	CNT	0699	CNT	0749	α	0799	X	0849	S/R	0899	0

Fig. 5.3

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STEP	KEY	STEP	KEY	STEP	KEY	STEP	KEY	STEP	KEY	STEP	KEY
0900	LBL	0950	1	1000	IND	1050	XFR	1100	CNT	1150	CNT
0901	4	0951	XTO	1001	a	1051	0	1101	CNT	1151	CNT
0902	CNT	0952	+	1002	CNT	1052	6	1102	XFR	1152	DN
0903	CNT	0953	a	1003	CNT	1053	5	1103	0	1153	-
0904	CNT	0954	CNT	1004	XTO	1054	CNT	1104	6	1154	DN
0905	XTO	0955	CNT	1005	0	1055	CNT	1105	4	1155	CNT
0906	b	0956	XFR	1006	6	1056	UP	1106	UP	1156	CNT
0907	CNT	0957	IND	1007	8	1057	XFR	1107	XFR	1157	CNT
0908	CNT	0958	a	1008	CNT	1058	0	1108	0	1158	CNT
0909	1	0959	CNT	1009	CNT	1059	6	1109	6	1159	XTO
0910	-	0960	CNT	1010	1	1060	9	1110	9	1160	0
0911	3	0961	XTO	1011	XTO	1061	X	1111	X	1161	6
0912	X	0962	0	1012	+	1062	CNT	1112	CNT	1162	3
0913	5	0963	6	1013	a	1063	CNT	1113	CNT	1163	CNT
0914	1	0964	6	1014	CNT	1064	XFR	1114	DN	1164	CNT
0915	+	0965	CNT	1015	CNT	1065	0	1115	-	1165	CNT
0916	CNT	0966	CNT	1016	XFR	1066	6	1116	DN	1166	CNT
0917	CNT	0967	b	1017	IND	1067	6	1117	CNT	1167	CNT
0918	YTO	0968	UP	1018	a	1068	UP	1118	CNT	1168	CNT
0919	a	0969	1	1019	CNT	1069	XFR	1119	CNT	1169	CNT
0920	CNT	0970	-	1020	CNT	1070	0	1120	XTO	1170	CNT
0921	CNT	0971	3	1021	XTO	1071	6	1121	0	1171	XSQ
0922	XFR	0972	X	1022	0	1072	8	1122	6	1172	UP
0923	IND	0973	5	1023	6	1073	X	1123	2	1173	CNT
0924	a	0974	1	1024	9	1074	CNT	1124	CNT	1174	CNT
0925	CNT	0975	+	1025	CNT	1075	CNT	1125	CNT	1175	XFR
0926	CNT	0976	CNT	1026	CNT	1076	DN	1126	CNT	1176	0
0927	XTO	0977	CNT	1027	CNT	1077	-	1127	CNT	1177	6
0928	0	0978	YTO	1028	CNT	1078	DN	1128	XFR	1178	2
0929	6	0979	a	1029	CNT	1079	CNT	1129	0	1179	XSQ
0930	4	0980	CNT	1030	CNT	1080	CNT	1130	6	1180	+
0931	CNT	0981	CNT	1031	CNT	1081	CNT	1131	4	1181	CNT
0932	CNT	0982	XFR	1032	CNT	1082	XTO	1132	UP	1182	CNT
0933	1	0983	IND	1033	CNT	1083	0	1133	XFR	1183	XFR
0934	XTO	0984	a	1034	CNT	1084	6	1134	0	1184	0
0935	+	0985	CNT	1035	CNT	1085	1	1135	6	1185	6
0936	a	0986	CNT	1036	CNT	1086	CNT	1136	8	1186	1
0937	CNT	0987	XTO	1037	CNT	1087	CNT	1137	X	1187	XSQ
0938	CNT	0988	0	1038	CNT	1088	CNT	1138	CNT	1188	+
0939	XFR	0989	6	1039	CNT	1089	CNT	1139	CNT	1189	CNT
0940	IND	0990	7	1040	CNT	1090	XFR	1140	XFR	1190	CNT
0941	a	0991	CNT	1041	CNT	1091	0	1141	0	1191	DN
0942	CNT	0992	CNT	1042	CNT	1092	6	1142	6	1192	r
0943	CNT	0993	1	1043	CNT	1093	6	1143	5	1193	CNT
0944	XTO	0994	XTO	1044	CNT	1094	UP	1144	UP	1194	CNT
0945	0	0995	+	1045	CNT	1095	XFR	1145	XFR	1195	CNT
0946	6	0996	a	1046	CNT	1096	0	1146	0	1196	CNT
0947	5	0997	CNT	1047	CNT	1097	6	1147	6	1197	XTO
0948	CNT	0998	CNT	1048	CNT	1098	7	1148	7	1198	0
0949	CNT	0999	XFR	1049	CNT	1099	X	1149	X	1199	6

Fig. 5.4

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STEP	KEY	STEP	KEY	STEP	KEY	STEP	KEY	STEP	KEY	STEP	KEY
1200	A	1250	H	1300	CNT						
1201	CNT	1251	DN	1301	CNT						
1202	CNT	1252	DIV	1302	CNT						
1203	CNT	1253	DN	1303	CNT						
1204	CNT	1254	L	1304	CNT						
1205	CNT	1255	M	1305	CNT						
1206	CNT	1256	CNT	1306	CNT						
1207	CNT	1257	CNT	1307	CNT						
1208	CNT	1258	XTO	1308	CNT						
1209	CNT	1259	b	1309	CNT						
1210	UP	1260	CNT	1310	FMT						
1211	XFR	1261	CNT	1311	FMT						
1212	0	1262	CNT	1312	L						
1213	6	1263	CNT	1313	O						
1214	3	1264	CNT	1314	N						
1215	CNT	1265	CNT	1315	G						
1216	UP	1266	CNT	1316	I						
1217	G	1267	CNT	1317	XTO						
1218	KEY	1268	CNT	1318	1/X						
1219	DIV	1269	CNT	1319	D						
1220	RUP	1270	CNT	1320	E						
1221	DIV	1271	CNT	1321	FMT						
1222	DN	1272	CNT	1322	CNT						
1223	L	1273	CNT	1323	b						
1224	M	1274	CNT	1324	CNT						
1225	XTO	1275	FMT	1325	CNT						
1226	a	1276	FMT	1326	CNT						
1227	CNT	1277	L	1327	CNT						
1228	CNT	1278	A	1328	CNT						
1229	CNT	1279	XTO	1329	CNT						
1230	CNT	1280	I	1330	CNT						
1231	CNT	1281	XTO	1331	K						
1232	CNT	1282	1/X	1332	7						
1233	CNT	1283	D	1333	CNT						
1234	CNT	1284	E	1334	CNT						
1235	UP	1285	FMT	1335	RUP						
1236	XFR	1286	CNT	1336	PNT						
1237	0	1287	CNT	1337	RUP						
1238	6	1288	a	1338	PNT						
1239	1	1289	K	1339	RUP						
1240	CNT	1290	7	1340	PNT						
1241	RUP	1291	CNT	1341	PNT						
1242	H	1292	CNT	1342	CNT						
1243	XTO	1293	RUP	1343	CNT						
1244	0	1294	PNT	1344	S/R						
1245	6	1295	RUP	1345	CNT						
1246	0	1296	PNT	1346	CNT						
1247	CNT	1297	RUP	1347	CNT						
1248	RUP	1298	PNT	1348	CNT						
1249	H	1299	PNT	1349	END						

Fig. 5.5

PROGPAM VOR

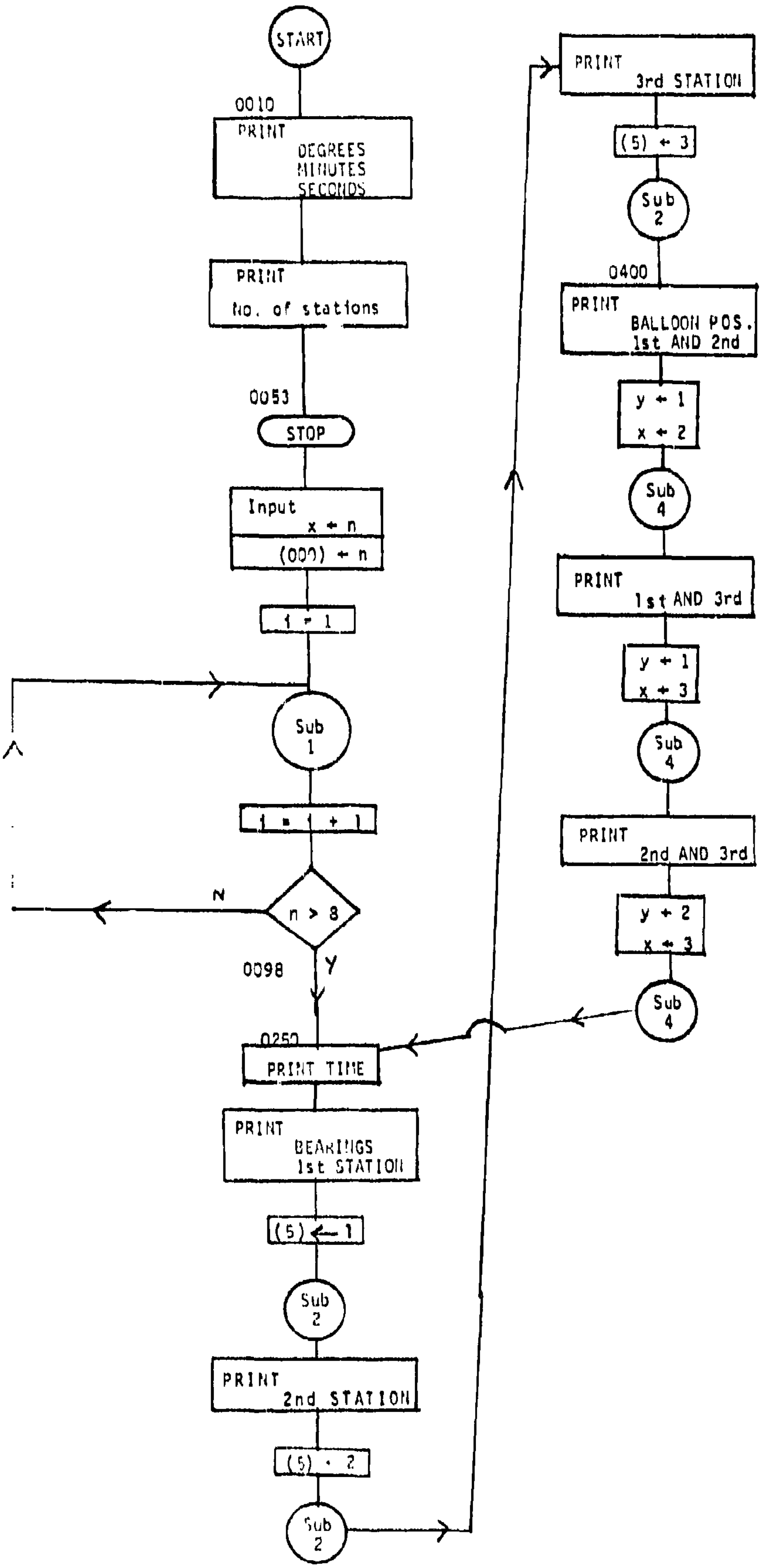
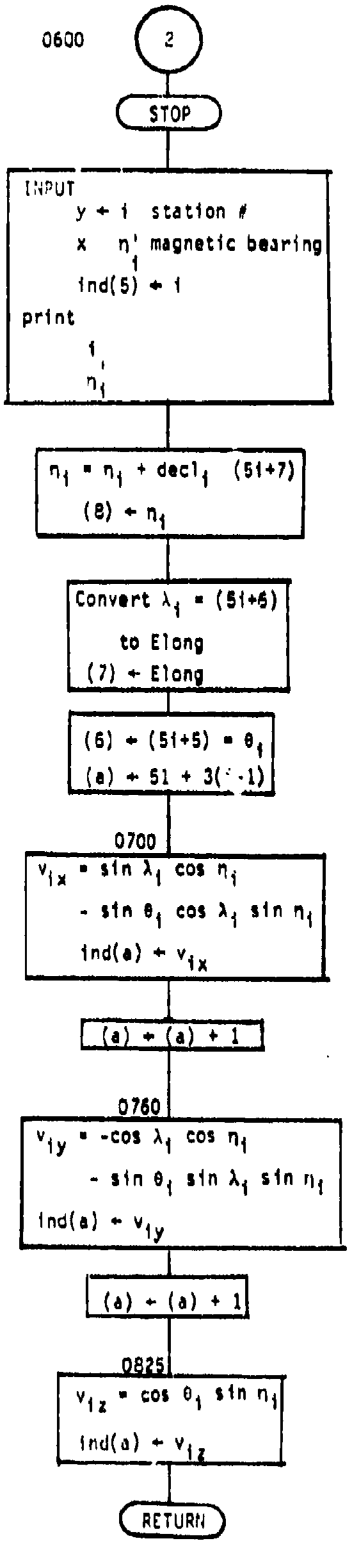


Fig. 6.1

SUBROUTINE $v_i = OS_i \times S_iB$



SUBROUTINE $y=n_1,\ x=n_2$

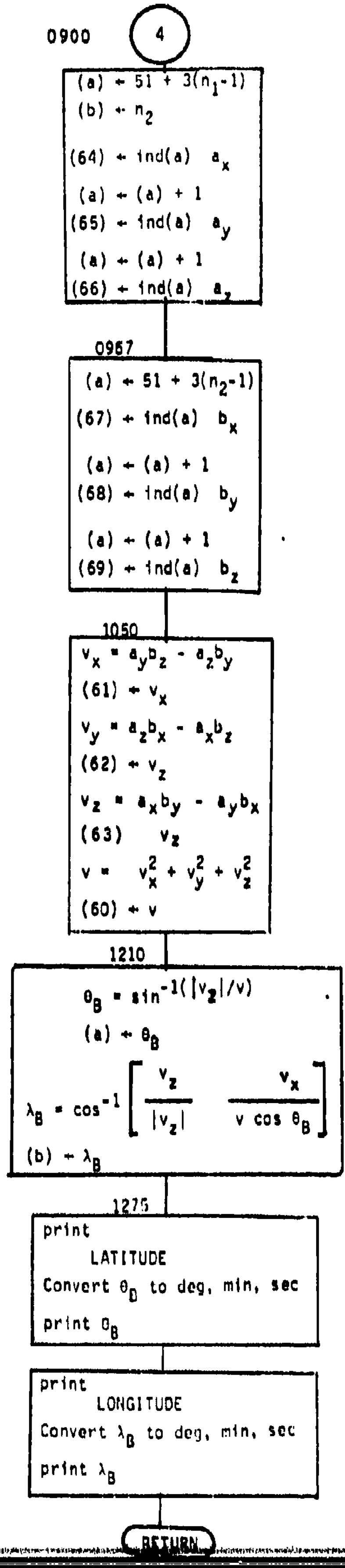


Fig. 6.2

SUBROUTINE i

SUBROUTINE A

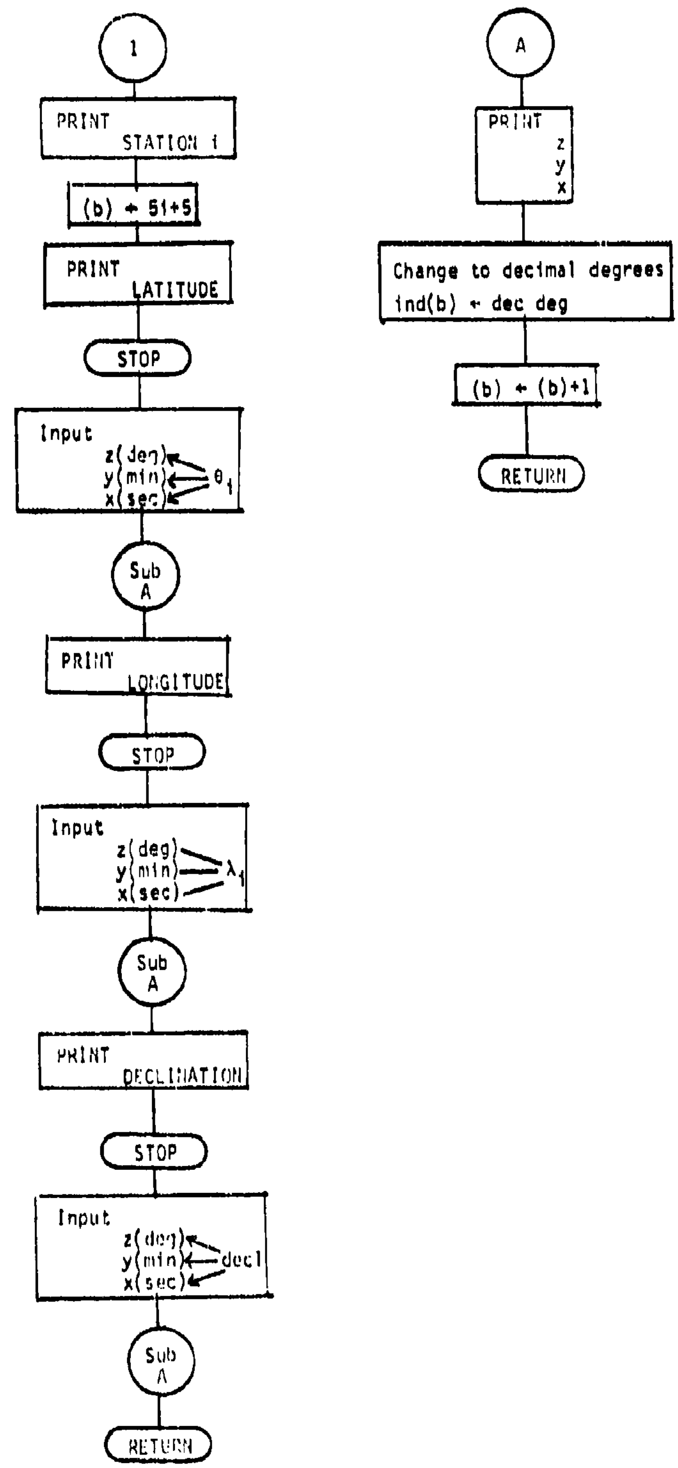
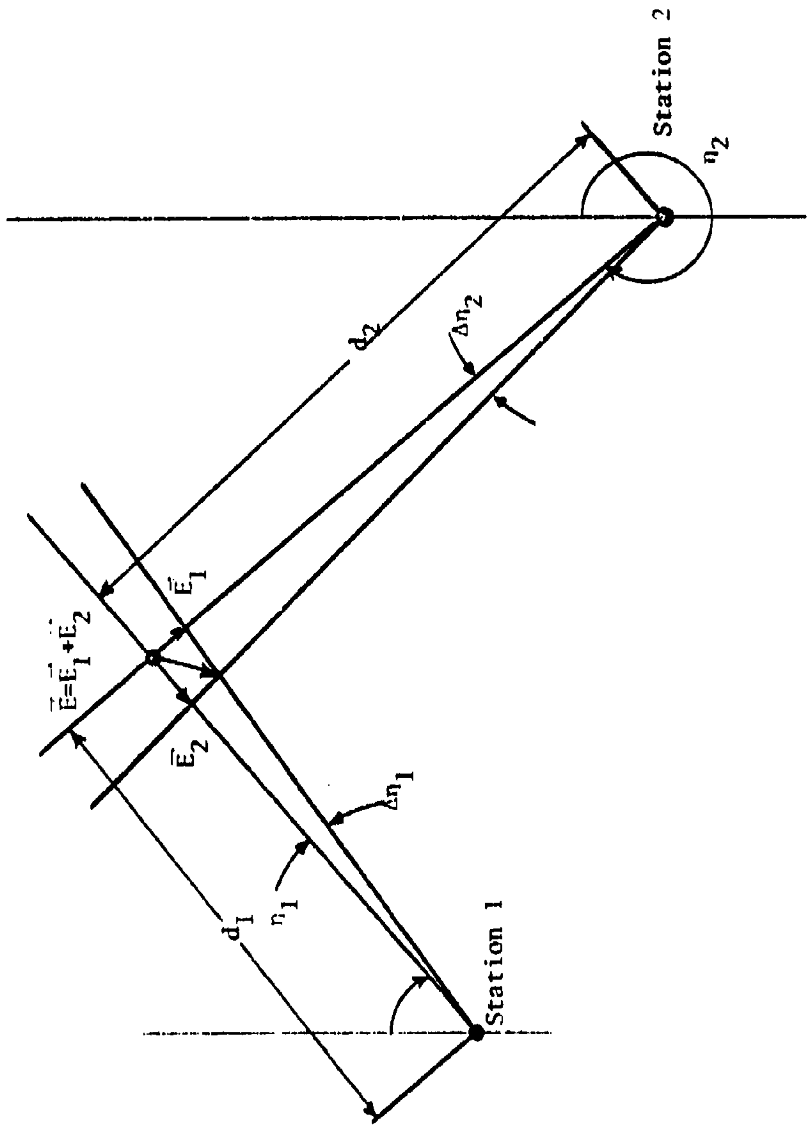


Fig. 6.3

000	# of stations		035	θ_6	
001	# of 1st station		036	λ_6	Station #6
002	# of 2nd station		037	$decl_6$	
003	# of 3rd station		038		
004			039		
005	i		040	θ_7	
006	θ_{n_i}		041	λ_7	Station #7
007	λ_{n_i}		042	$decl_7$	
008	η_{n_i}		043		
009			044		
010	θ_1		045	θ_8	
011	λ_1	Station #1	046	λ_8	Station #8
012	$decl_1$		047	$decl_8$	
013			048		
014			049		
015	θ_2		050		
016	λ_2	Station #2	051	v_{1x}	
017	$decl_2$		052	v_{1y}	
018			053	v_{1z}	Registers 71-108
019			054	v_{2x}	are not used
020	θ_3		055	v_{2y}	
021	λ_3	Station #3	056	v_{2z}	
022	$decl_3$		057	v_{3x}	
023			058	v_{3y}	
024			059	v_{3z}	
025	θ_4		060	$\|v\|$	
026	λ_4	Station #4	061	v_x	
027	$decl_4$		062	v_y	
028			063	v_z	
029			064	$v_{n1,x}$	
030	θ_5		065	$v_{n1,y}$	
031	λ_5	Station #5	066	$v_{n1,z}$	
032	$decl_5$		067	$v_{n2,x}$	
033			068	$v_{n2,y}$	
034			069	$v_{n2,z}$	

Fig. 7



Station 2
η_2
d_2
$\Delta\eta_2$
$\vec{E}_1$
$\vec{E}=\vec{E}_1+\vec{E}_2$
$\vec{E}_2$
$\Delta\eta_1$
η_1
d_1
Station 1

Fig. 8

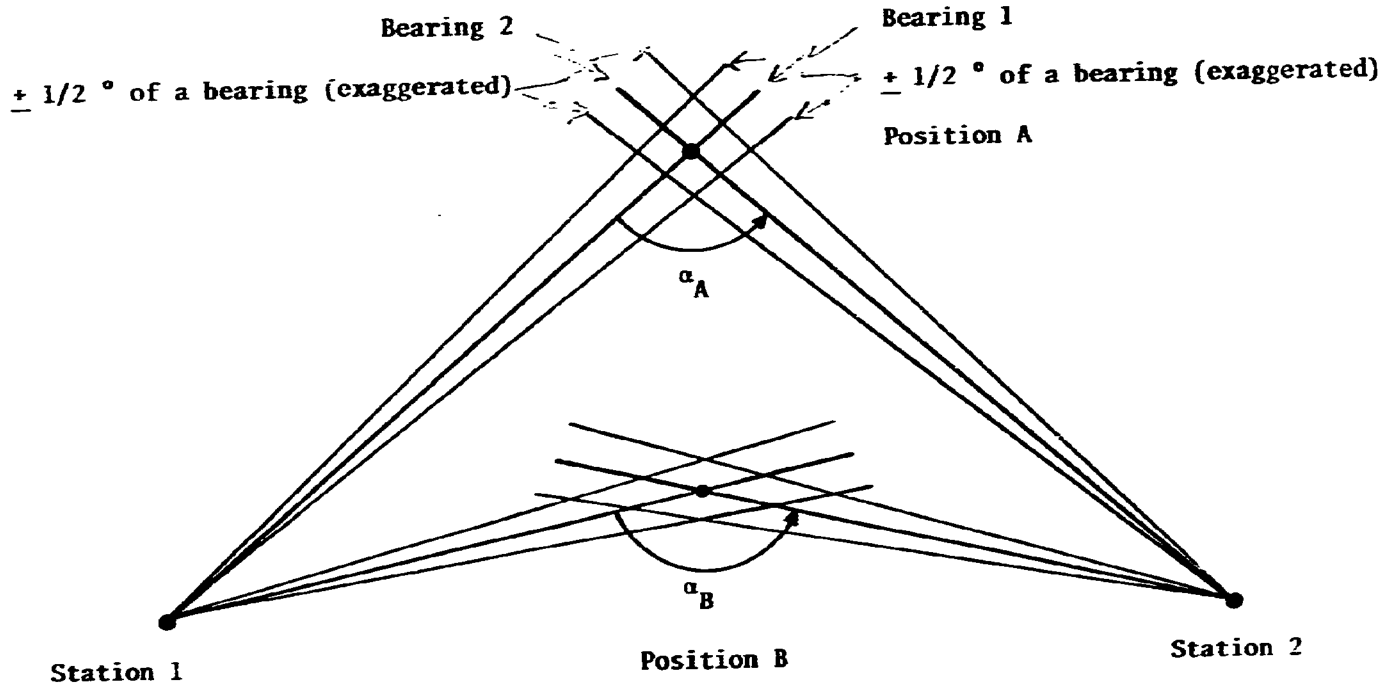

Bearing 2
± 1/2 ° of a bearing (exaggerated)
Bearing 1
± 1/2 ° of a bearing (exaggerated)
Position A
α_A
α_B
Station 1
Position B
Station 2

Fig. 9

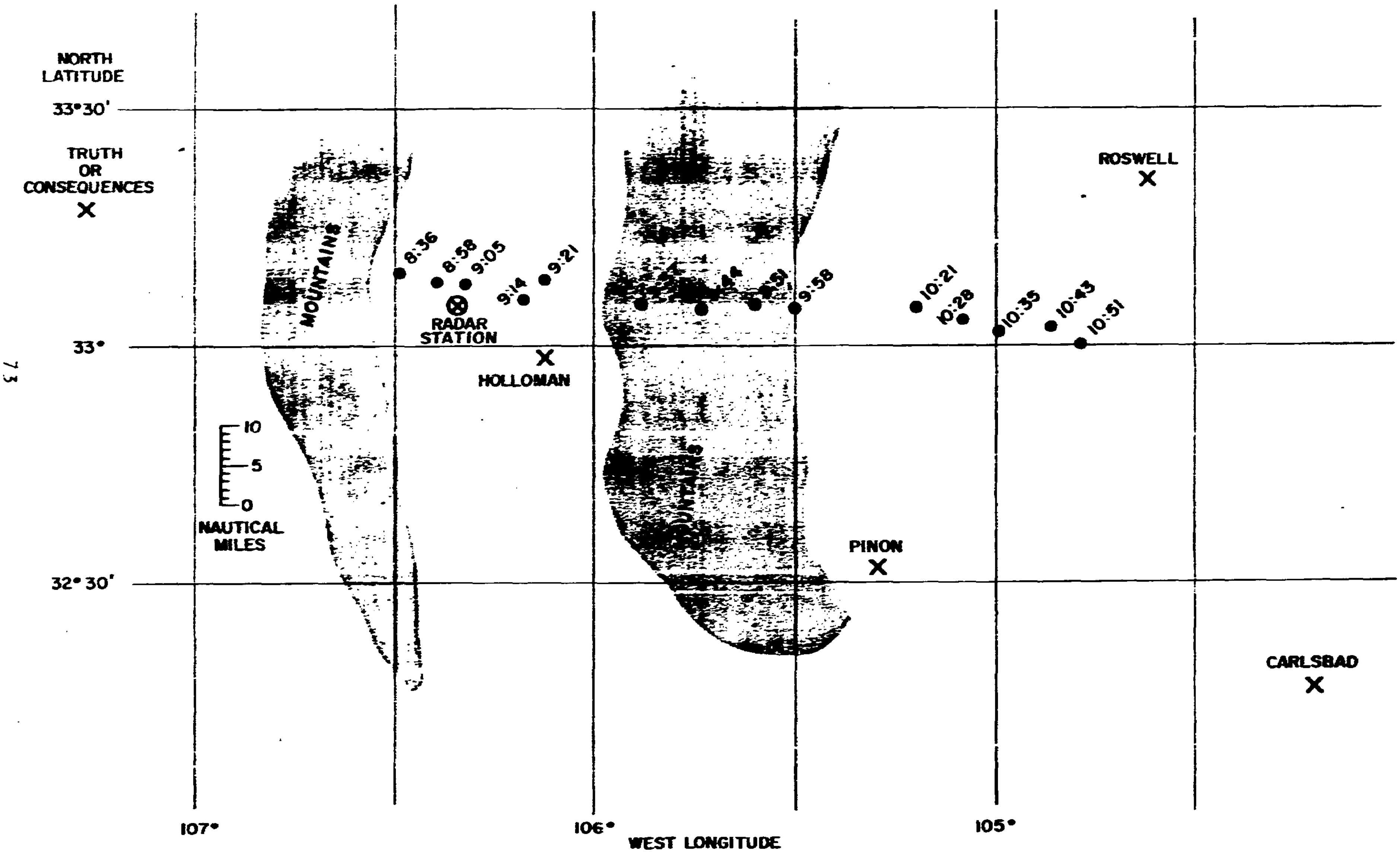

NORTH LATITUDE
33°30'
33°
32°30'
TRUTH OR CONSEQUENCES
MOUNTAINS
8:36
8:58
9:05
9:14
9:21
RADAR STATION
HOLLOMAN
9:58
10:21
10:28
10:35
10:43
10:51
ROSWELL
PINON
CARLSBAD
10
5
0
NAUTICAL MILES
107°
106°
105°
WEST LONGITUDE

FIG. 10

III. Tethered-Balloon Experiment

Introduction

A series of tests was made in February-March 1975 to aid in the implementation of the'Tactical Loran Tritether Instrumentation Hook-up'. These tests consisted of flying a 30000 cu ft balloon on tethers of various lengths (100, 500, 1000, and 2000 ft) with various loads (from no load up to 260 lbs) in various winds. The purpose of these tests was to determine the extent of balloon wander under different wind conditions. The balloon position was measured by means of theodolites, and wind azimuth and velocity were measured by instruments attached just under the balloon. Table 1 gives a summary of the different runs made in this series of tests.

Analysis

At the beginning the approach was to plot individual data points, with each graph containing data from only one run. Balloon positions with respect to ground zero were plotted with the y-axis representing north and the x-axis east. Values of wind direction and azimuth corresponding to each balloon position were also plotted on those graphs, with the distance from the origin corresponding to the wind velocity and the angle with respect to the y-axis corresponding to the wind azimuth. The two sets

of points were numbered and connected by straight lines, providing a kind of time history of the balloon position, wind direction, and wind speed.

Using the corresponding values of wind azimuth, the balloon positions were then resolved into components parallel and perpendicular to the wind. These values were also plotted as a function of time.

Since not much could be inferred from those types of plots, since the wind data might not have been good enough to justify a point-to-point breakdown, and since it takes a certain amount of time for a given change in wind direction or speed to effect a change in balloon position, it was decided to group together those times when both wind speed and direction were 'approximately constant.' Balloon positions during a given time period were resolved into components parallel and perpendicular to the wind based on the average azimuth of the wind over the whole period. Each time period contains at least five points, and, for some runs in which the wind was nearly constant, it was not necessary to divide the data at all. Balloon positions parallel and perpendicular to the wind were graphed versus time, and each run was graphed separately.

Since this type of time history of balloon wander did not seem to provide any notable insights, data from each of those time periods were grouped together, and statistics

of mean, standard deviation, maximum excursion from ground zero, and spread of excursions about ground zero were calculated. These are statistics of the balloon displacement from ground zero both parallel and perpendicular to the wind. Hence, for each time period of a given run one value for each of the above statistics of balloon displacement was calculated, both parallel and perpendicular to the wind.

In the next set of graphs, each of the statistics of displacement listed above was plotted versus the average wind velocity of the corresponding time interval. Each graph contained the data from all runs of a given tether length, for a given statistical parameter either parallel or perpendicular to the wind. If a particular run was divided into more than one time interval, more than one set of statistics were plotted for that run.

Note that in the case of maximum and minimum excursions, the length of the time interval of the run is important; however, no attempt was made to take this into consideration. On the other hand, in the case of the mean and standard deviation, the length of the time interval is not important as long as it is 'long enough' to provide a representative sample.

From this set of graphs it was seen that in the runs of the 100' tether the balloon wander is a much higher fraction of the cable length than with the other tether lengths.

Note that, in the application for which this will be used, it is the zenith angle of the balloon tether which is important. From this set of graphs it was decided that the 100' tether was not suitable.

One can also see that the 1000' and 2000' tethers are noticeably better than the 500' tether. However, it was felt that performance of these lengths would not justify their use over the 500' tether. Use of a longer cable increases the weight, thereby decreasing the net lift of the balloon, and makes the rigging of the balloon more difficult

Since it is the zenith angle of the balloon tether which is important in this applicaiton, the statistics of balloon displacement listed above were converted to percentage displacement (=displacement/cable length x 100). Each statistic was plotted separately versus average wind velocity. For a given statistic, the data for the 500', 1000', and 2000' tethers parallel or perpendicular to the wind were plotted on the same graph.

For mean displacement parallel to the wind, the percentage displacement increases with wind velocity in a way which is almost linear. There is no noticeable dependence on tether length apart from the fact that the 500' tether does not perform quite as well as the two longer tethers. There is a fair amount of scatter in the graph, but the slope of that line which produces the best fit is 1.7% of cable length per

mph of average wind velocity. Therefore, the degree to which the balloon is blown back into the wind is proportional to the average wind velocity.

Mean displacement perpendicular to the wind showed no systematic variation with wind velcoity. This is reasonable since the balloon should not have a preferred average position perpendicular to the wind.

Standard deviaiton parallel and perpendicular to the wind is very variable and, with the exception of winds below 5 mph, shows no variation with wind velocity. Furthermore, the 500' tether data have noticeably higher standard deviations than do the 1000'- or 2000'- tether data. Note that even in high winds, greater than 20 mph, the standard deviation did not increase.

The maximum excursion from ground zero parallel to the wind showed an almost linear increase with wind velocity, but with considerable spread. Again the 500' tether shows, in general, greater displacements than do the two longer tether lengths.

The spread of excursions parallel to the wind shows no relation to wind velocity above 5 mph. But, here again, the 500' tether shows greater displacements.

The variation of these two statistics perpendicular to the wind also showed no variation with wind velcoity above 5 mph, but the 500' tether showed significantly greater

displacements than did the two longer tether lengths.

We have seen that parallel to the wind the mean and maximum excursion varied with wind velocity in an almost linear fashion. Dividing each of these statistics by wind velocity, (producing a mean or maximum displacement /mph average wind velocity), these data were plotted versus load to try to find what effect, if any, the load might have on balloon wander. Qualitatively, we know that an increase in the load will increase the angle of attack of the balloon. Up to a certain point this is desirable since it produces an increase in aerodynamic lift, but after this point the aerodynamic lift decreases with angle of attack.

For the "mean displacement parallel to the wind/mph average wind velocity", there seemed to be some correlation with load, i.e., angle of attack. The spread is very large, but one can conclude that the slope of the percentage mean displacement parallel to the wind versus wind velocity is higher when the load is greater.

The slopes computed using the percentage-maximum-excursion statistics show, on the other hand, no correlation with load.

Summary

1) Data were first resolved into components parallel and perpendicular to the wind.

2) Data were then grouped together into time periods when both the speed and azimuth of the wind were constant.

3) Data for each time period during which the wind was constant were then grouped together to form statistics of the displacement of the balloon with respect to ground zero both parallel and perpendicular to the wind.

4) The percentage displacement of the 100' tether was too high to be suitable for this application. The percentage displacements for the 1000' and 2000' tethers were noticeably smaller than those of the 500', but their performance was not that much better to justify their use over the shorter 500' tether.

5) Percentage mean displacement parallel to the wind varied linearly with wind velocity, with a slope of 1.7%/mph, the balloon being blown back into the wind more and more as the wind increased. Perpendicular to the wind the mean displacement showed no variation with wind velocity, i.e., the balloon had no preferred position perpendicular to the wind.

6) Maximum excursion parallel to the wind varies linearly with wind velocity. This is due to a great extent, however, to the variation of the mean. Perpendicular to the wind there is no systematic variation.

7) Standard deviation parallel and perpendicular to the wind showed no variation with the wind above 5 mph.

8) In the case of the standard deviation parallel and perpendicular to the wind and of the maximum excursion parallel to the wind, the 500' tether showed greater percentage displacements, in general, than did the two longer tethers.

9) Load, in general, seems to produce greater displacements parallel to the wind.

Table 1

	NO LOAD	LOAD BAR ONLY	LOAD BAR +140 LBS BALLAST	LOAD BAR +265 LBS BALLAST
2000' tether	2/26 #4	3/7 #2*	2/27 #8	3/7 #1
	2/27 #4	3/7 #3	2/28 #4	
	3/4 #4*		3/6 #4	
1000' tether	2/26 #3	3/7 #4*	2/27 #7	3/3 #3
	2/27 #3		2/28 #3	
	3/4 #3		3/6 #3	
500' tether	2/26 #2	2/26 #5	2/27 #6	3/3 #2*
	2/27 #2	3/3 #5	2/28 #2	3/7 #6
	3/4 #2		3/6 #2	
100' tether	2/26 #1	3/3 #4	2/27 #5	3/3 #1*
	2/27 #1		2/28 #1	3/7 #5
	3/4 #1		3/4 #5	
			3/6 #1	

* NO WIND DATA

IV Balloon-Flight Simulation

The following balloon-flight simulations were done.

A. Eglin AFB simulation

Using 10 years of wind data from Eglin AFB, balloon positions and statistics of balloon positions were calculated assuming an ascent to 10 mb at a constant ascent rate of 800 ft/min, letting the balloon float for 0, 1, 4, 6, 8, and 10 hours at 10 mb. This was done using wind data for days 1-10, 11-20, and 21-31 in each of the months from April to September.

The wind data were received on a 9-track, phase-encoded tape which had to be converted to a 7-track tape in order to make it compatible with the CDC 6600 at AFGL. Before writing the 7-track, 800-bpi tape the data were sorted by month and day.

The balloon positions and associated statistics were done by a program called CHICSIM, which was modified for this particular job.

B. Holloman and White Sands simulation

Using 10 years of wind data from Holloman and White Sands, balloon positions and statistics of balloon positions were calculated assuming ascents to 80, 90, and 100 kft, at a constant ascent rate of 800 ft/min, letting the balloon float for 0, 2, 4, 6, 8, 10, and 12 hours at each of those altitudes.

Each of the above cases was run for days 1-15 and 16-31 for all months of the calendar year.

These wind data were already on a CDC 7-track tape. The data were processed by a program called SIMBALL, which was modified slightly for this particular job.